



INDIAN AGRICULTURAL
RESEARCH INSTITUTE, NEW DELHI.

17094-95/36

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COMMONWEALTH



OF AUSTRALIA

JOURNAL

OF

THE COUNCIL FOR SCIENTIFIC

AND

INDUSTRIAL RESEARCH

VOLUME 5.
1932.

Editor: G. A. COOK, M.Sc., B.M.E.

Annual Subscription, 5s. Post Free

By Authority :
H. K. Gifford, Government Printer, Melbourne

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FEBRUARY, 1932.

No. 1.

Wood Taint in Butter : Laboratory Experiments with Special Reference to *Pinus radiata* (*insignis*) and Hoop Pine (*A. cunninghamii*).

By W. J. Wiley, M.Sc.

Mr. Wiley is a graduate of the University of Queensland who has recently returned to Australia after obtaining two years' post-graduate experience at the Dairying Research Institute at Reading, England, as a student under the Science and Industry Endowment Fund (see this Journal, 1: 99, 1927). His work on butter taint was carried out under the general direction of a Committee consisting of Mr. I. H. Boas (Chief of the Division of Forest Products, C.S.I.R.), Dr. W. J. Young (Associate-Professor of Biochemistry, University of Melbourne), and Mr. P. J. Carroll (Supervisor of Dairy Exports, Commonwealth Department of Markets). The chemical portion of the investigations was carried out in the Biochemical Department of the University of Melbourne. Work on other aspects of the investigation, for example those relating to the larger scale tests, the use of various timbers, &c., was carried out at the Division of Forest Products laboratories at Albert-street. Actual storage tests were made in various centres in Adelaide, Melbourne, Sydney, and Brisbane.

In his second article, Mr. Wiley has indicated the help given by organizations and individuals other than those mentioned above, and in particular the generous grant of £300 by the Australian Dairy Council. To all who have assisted, the Council tenders its grateful thanks for their helpful co-operation.
—ED.

Summary.

The "wood taint" in butter imparted by *P. radiata* is due to slightly volatile oil. The smell and flavour sometimes imparted by hoop pine are due to different substances in the wood not necessarily always occurring together. The only wrapping material of several tested which was found to be less permeable to the tainting vapours than the usual parchment was "waterproof" cellophane. A simple laboratory test is described for determining the tainting properties of a wood.

Work on protective coatings is proceeding and is reported in the second article.

1. Introduction.

The taint sometimes given to butter by the wood of the container is of particular importance to the Australian dairy industry. Owing to the storage period necessitated by transport before export butter is placed on the market, there is every opportunity for the taint to develop, and reports* have been received showing serious de-grade in some export butters due to wood taint. The subject is also of considerable importance to the Australian timber industry, as a large proportion of the butter boxes used are manufactured of imported timber. Experience has shown that New Zealand white pine (*Podocarpus daeydioides*) is a satisfactory timber, as complaints of wood taint from its use are rare, it is of pleasing appearance, and has desirable mechanical properties. Many butter manufacturers thus continue to use it, although boxes of Australian timber are available.

* Wigan, F. Reports to the Commonwealth Department of Markets, 1928-9.

The Australian timber which has been most used is Queensland hoop pine (*Araucaria cunninghamii*). It has been in use chiefly in Queensland for many years, but occasional complaints of the tainting of butter from boxes made of it have hindered its more general adoption.

The magnitude of the butter box industry can be judged from the fact that during the 1930-31 season nearly 3,000,000 boxes were exported and many more used in the local trade.

2. Previous Work.

Considerable experimental work has been done at various times on hoop pine as a timber for butter boxes. In 1902, F. B. Guthrie records* a few experiments in which Richmond River pine (hoop pine) proved as suitable as New Zealand white pine, and in 1906, Queensland hoop pine† was found to be satisfactory. These experiments were performed in view of the "probable shortage of New Zealand white pine." However, complaints of wood taint were occasionally received and numerous small experiments were made. In 1925, the Institute of Science and Industry‡ as the result of inquiries, summarized the then available knowledge as follows :—

1. All kinds of wood, however well seasoned, cause some taint in butter if it is packed in contact with the wood. A lining of special "butter paper" is sufficient to prevent the taint.
2. Certain woods, well seasoned and dry, can be used without fear of taint if the boxes are lined with butter paper, e.g., New Zealand white pine, Queensland hoop pine, Swedish white pine, and American spruce and white fir.
3. Some woods, if used unseasoned, produce taint even when the usual paper lining is used, but when well seasoned and lined with paper can be used without producing wood taint, e.g., Queensland hoop pine.
4. Some woods, irrespective of seasoning, will taint the butter through the paper lining, e.g., black heart or sinker pine of Queensland.
5. The timbers which have given satisfactory results with paraffining the wood or with lining the box with paraffined cardboard are those which have given satisfactory results without the paraffining or the use of paraffined cardboard.

Complaints of serious wood taint from hoop pine became more insistent soon after this, and in 1929 a Committee was set up in Queensland containing representatives of the dairying and timber interests. This Committee§ made many practical experiments, and its final conclusions were summarized as follows :—

1. The defect referred to as wood taint in butter affects the surface only, usually penetrating not more than one-eighth of an inch.
2. It occurs mostly along the corners and on the top surface.
3. The defect is usually associated with air spaces or where air has contact with the butter.
4. All species of timber may be associated with the defect.
5. The seasoning of the wood does not prevent the incidence of the taint.
6. Knotty timber and green timber are generally no more associated with the defect than first class clean pine.

Double papering does not prevent the taint although it retards it.

8. Horizontal papering and top surface covering is a distinct advantage in retarding the incidence of the taint.

9. No timber produces any more satisfactory results than properly seasoned Queensland pine.

* Guthrie, F. B. *Agric. Gaz. of N.S.W.* 13 : 314. 1902.

† Guthrie, F. B. *Agric. Gaz. of N.S.W.* 17 : 1906.

‡ Report to the Australian Dairy Council, 17th June, 1925 (unpublished).

§ I am greatly indebted to the Queensland Wood Taint Committee for its courtesy in making available to me all its experimental results and freely discussing different aspects of the subject.

The experience of years and experimental results show that hoop pine does sometimes taint butter. It is just as certain that it is sometimes a suitable wood imparting no taint to the butter. None of the experiments so far reported have indicated the reasons for this variability, or a certain means of detecting unsuitable timber. The erratic nature of the results obtained caused some doubt as to whether "wood taint" when applied to butter from hoop pine boxes really was due to the timber, and it was suggested that it might be of bacterial origin. Moreover, until some means was evolved of determining which samples would taint, it was considered useless to carry out practical butter-packing experiments with different wrapping materials or treatment of the timber with a view to preventing the taint. It is obvious too that any experiments in this direction would be on a sounder footing if the actual cause of the tainting were first definitely established. The laboratory work recorded in this paper was therefore undertaken.

A complicating factor in the investigation of hoop pine is the occasional occurrence of what are known as "sinker" or "stinker" logs. Both terms are descriptive. The first term was applied because of the comparatively high density of these logs which caused them to sink during the logging operations common in the early days of the timber industry. They emit a particularly nauseating odour which is not lost in seasoning although becoming somewhat less intense. The timber is sometimes dark in colour. Although boxes made of it would be expected to taint butter, the results of the Queensland Wood Taint Committee showed that this did not invariably happen. Wood of this type will be referred to in this paper as "stinker" pine, but it must be clearly understood that such wood is not typical of hoop pine, and badly smelling boards would not be used by the conscientious miller in making butter boxes. However, there is a gradation from the non-odorous hoop pine to strong-smelling wood. The reason for the occurrence of these logs has not been investigated, but from inquiries it appears that the trees always exhibit some signs of injury and there is a probability of infection with disease.

Pinus radiata (insignis) is a timber which has been extensively planted in South Australia and is now at the production age. Large and continuous supplies will shortly be available. Experiments with this wood for butter boxes in South Australia have shown that it imparts a characteristic taint to the butter. Some laboratory work was therefore done with it.

The most probable reason for wood tainting appeared to be the occurrence of a highly-flavoured, volatile, fat-soluble constituent of the wood which could permeate through the parchment lining of the box, and by dissolving in the butter impart a taint. The experiments were directed with the object of testing this hypothesis.

3. Experimental Work.

The first experiments were made with the apparatus shown in Fig. 1. In this an electric fan *A*, with extended shaft, blows a current of air through a layer of wood shavings contained in the metal cylinder *B*, on to the surface of butter *C* supported beneath *B*. The apparatus is enclosed in a box lined with galvanized iron, and the air circulates continually through the wood shavings and on to the butter surface. The fan is 12 inches in diameter. The metal cylinder *B* is 13 inches in diameter and 20 inches long, the lower 6 inches being tapered to a diameter of 6 inches. The butter is contained in a clock glass of 6 inches diameter. The shavings in *C* are supported on a wire gauze fastened where shown in the figure. A loose

fitting circle of gauze placed above them prevents them being blown out of *B* by the fan. They are loosely packed so as not to hinder the passage of air materially. *B* is supported by metal rings in the containing box so that it can be readily lifted out. The lid of the containing box which supports the fan and the cover of a small opening for giving ready access to the butter are clamped on with bolts and wing nuts.

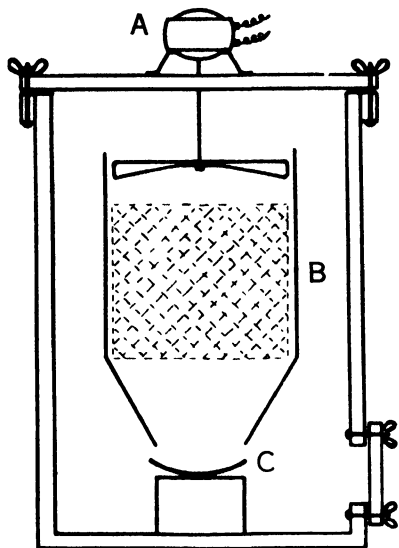


FIG. 1.

With a 6-in. depth of shavings of *P. radiata*, cut with a hand plane from the edge of a $\frac{3}{4}$ -in. board, placed in the container in this apparatus, it was found that after the fan had been running half an hour the butter had a distinctly tainted smell and flavour, the taint being reminiscent of turpentine and apparently identical with that obtained in practice from boxes made of this timber. After one hour's run the taint was somewhat stronger, and after 3 hours was of approximately the same strength as after 1 hour.

A particularly bad sample of "stinker" hoop pine gave similar results. The taint was distinct in half an hour, somewhat stronger after 1 hour, and of about the same strength after 3 hours. The taint was typical of that in butter tainted by hoop pine boxes in the usual way. The tainting smell of the butter decreased notably after exposure to the air for half an hour, but

long exposure made little difference to the flavour. Two samples each of New Zealand white pine and of white non-odorous hoop pine when tested in this machine gave no taint to the butter after exposures up to 5 hours. Four samples of hoop pine taken from butter boxes which had tainted gave a typical definite taint to the butter after half an hour in the machine. Four samples of thoroughly kiln-dried *P. radiata* all tainted the butter after half an hour.

Shavings from *P. radiata* and hoop pine, after being spread out exposed to the air for 3 weeks, tainted to much the same extent as before airing. After 5 months' drying, however, both lots of shavings were found to impart but an extremely faint taint. It should be noted that 3 weeks' exposure in the form of shavings would correspond to a far more thorough seasoning than the timber would probably ever have in practice. Kiln-dried *P. radiata* appeared to taint as badly as the unseasoned timber. These experiments thus confirm the conclusions that seasoning, as usually understood, has no effect on the tainting of butter by these woods. Very prolonged seasoning might diminish the intensity of the taint.

As the butter from some samples could become tainted in half an hour, the only probable explanation is the simple chemical one of a substance volatilizing from the wood and dissolving in the butter, for a bacterial taint could hardly develop in this time. As shavings after exposure to the air for 3 weeks still tainted but after 5 months gave but a faint taint, the substance must be but slowly volatile.

The apparatus then provides a ready means of testing samples of wood which are likely to taint butter. Experiments with it led to the following conclusions :—

1. Wood taint from *P. radiata* and hoop pine is due to substances dissolving in the butter which are slowly lost by volatilization from the wood.
2. Practical seasoning does not lead to an appreciable loss of these substances from the wood.

Further work was undertaken in order better to define the properties of the tainting substances. Aqueous extracts of stinker pine (a sample of which had been found to taint), *P. radiata*, and New Zealand white pine were prepared and poured on a layer of butter smeared on a clock glass and allowed to stand overnight. The extract was then poured-off, the surface of the butter washed with water and dried with filter paper. It was found that the butter from all the samples was but extremely faintly tainted, and although the stinker pine had imparted its smell to the butter surface, this was lost after half an hour's exposure to the air. This lack of tainting by the aqueous extract of the woods confirms previous work on the tainting from hoop pine.

Petroleum ether (B.P. below 60° C.) extracts of 10 grams of the same samples were prepared. The petrol was distilled off to a small bulk and the last few c.cs. evaporated on filter papers. These were placed on the surface of butter on watch glasses and allowed to remain overnight. New Zealand white pine extract gave a faint aromatic taste and smell to the butter. Stinker hoop pine extract gave a very faint smell not characteristic of the wood, but a strong flavour, typical of butter tainted by this wood. *P. radiata* extract gave a distinct smell and strong turpentine-like flavour to the wood typical of butter tainted by this wood.

Ten gram portions of the same samples powdered (40 mesh) were mixed with 500 c.c. of water and the mixture distilled, the first 100 c.c. being collected; 50 c.c. of this distillate, which was somewhat cloudy from all the timbers, was extracted three times with petrol ether and, after extraction, warmed carefully to drive off traces of petrol ether. The petrol solution was carefully evaporated down finally at room temperature on a clock glass which was inverted over one containing butter and allowed to stand overnight. The distillate and extracted distillate were tested for tainting power by being poured on butter smeared on a watch glass and allowed to stand overnight. The butter was graded next morning with the results shown in Table I.

TABLE I.

	Smell	Taste
<i>New Zealand White Pine—</i>		
Steam distillate	Faint ..	Distinct, reminiscent of cardboard
Same extracted with petrol ether	None ..	Very faint flavour of petrol ether
Petrol soluble portion	Faint ..	Distinct, similar to steam distillate
<i>P. radiata—</i>		
Steam distillate	Strong ..	Very strong
Same extracted with petrol ether	None ..	Faint flavour of petrol ether
Petrol soluble portion	Strong ..	Strong
<i>Stinker Hoop Pine—</i>		
Steam distillate	Strong ..	Very strong
Same extracted with petrol ether	Faint ..	Faint
Petrol soluble portion	None ..	Strong

It is apparent that the tainting substances are volatile in steam and extracted from the aqueous distillate by petrol ether.

A sample of stinker hoop pine was thoroughly extracted with petrol ether in a soxhlet apparatus. After extraction, the wood appeared to smell as strongly as before. When the extracted and un-extracted woods were steam distilled as above, however, it was found that only the un-extracted wood imparted a flavour to the butter, while both gave the characteristic smell which, however, the butter soon lost on exposure to the air. On extracting the wood with water, the odorous substance dissolved, and on distilling this extract came over entirely in the first portion of the distillate, as judged by smell.

The ready volatility in steam of the tainting substances is shown by the following experiment :—5 grams of powdered wood were mixed with 250 c.c. of water and the mixture distilled, the 1st, 3rd, 5th and 7th 25 c.c. portions being reserved, also the residue in the flask after distilling off this quantity of water.

These fractions tested on butter gave the results shown on Table II.

TABLE II.

			Smell.	Taste.
<i>Stinker Hoop Pine—</i>				
1st 25 c.c. portion	..	..	Very strong	Very strong
3rd 25 c.c. portion	..	..	Moderate ..	Moderate
5th 25 c.c. portion	..	..	Faint ..	Faint
7th 25 c.c. portion	..	..	None ..	None
Residue in flask	..	..	None ..	Very weak, but distinct caramel-like flavour, quite different from wood taint
<i>P. radiata—</i>				
1st 25 c.c. portion	..	..	Strong ..	Strong
3rd 25 c.c. portion	..	..	Faint ..	Definite
5th 25 c.c. portion	..	..	None ..	Extremely faint
7th 25 c.c. portion	..	..	None ..	None
Residue in flask	..	..	None ..	Weak, but distinct caramel-like flavour, quite different from wood taint

Similar experiments to those described above were made with five samples each of *P. radiata* and stinker hoop pine. These confirmed the results recorded above. The conclusions to be drawn are—

1. The flavour and odour imparted to butter by *P. radiata* are due to substances in the wood, insoluble in water, soluble in petrol ether, and readily volatile in steam.
2. The flavour imported to butter by "stinker" hoop pine is due to substances in the wood, insoluble in water, soluble in petrol ether, and readily volatile in steam.
3. The odour imparted to butter by "stinker" hoop pine is fugitive, disappearing when the butter is exposed to the air a few hours. It is due to a substance in the wood, soluble in water, and readily volatile in steam.

The distinction between the odour and flavour-producing substances in stinker hoop pine is interesting and explains some contradictory results obtained in previous experiments. While in all the experiments performed

by us it was found that samples which had a strong smell also imparted the "hoop pine" taint, it is possible that the smelling constituent of the wood is sometimes present without appreciable quantities of the flavour-producing substance. Several samples of hoop pine tested by us imparted a strong flavour to the butter although the wood had no objectionable odour. It is plain then that the odour of a sample of hoop pine is not an indication of its liability to taint, but as 12 samples of stinker pine tested in the laboratory all imparted the wood taint flavour to butter, such wood must be more liable to taint than normal hoop pine.

It is to be noted that the flavours imparted to the butter from "stinker" hoop pine, and those non-odorous samples which were found to taint the butter, were the same and identical with that observed in butter which has become tainted in the usual way from the box.

It will be noted in Table I. that the sample of New Zealand white pine, when treated as described, imparted a distinct taint to the butter, although this sample gave no taint when tested in the apparatus first described. Similar distillation tests of powdered samples of both New Zealand white pine and hoop pine, some of them from boxes which had not tainted, showed that by distilling in this manner a distillate could be obtained which tainted the butter. For example, a sample of New Zealand white pine and one of hoop pine, both from butter boxes which had not tainted butter after 10 weeks' storage, gave the following results.

Ten grams of the powdered wood were mixed with 500 c.c. of water and the 100 c.c. distilled from the mixture. The distillate was tested on butter in the following dilutions:—Full strength, 1 in 2, 1 in 4, and 1 in 8. The butter was arranged in the order shown in Table III. when graded.

TABLE III.

Timber.	Strength.	Taint.
1. Hoop Pine	Full strength	Distinct hoop pine type of taint
2. New Zealand White Pine ..	Full strength	Distinct New Zealand white pine taint
3. New Zealand White Pine ..	1 in 2 ..	Distinct New Zealand taint
4. Hoop Pine	1 in 2 ..	} Taint could be detected, but too faint to be sure of type
5. Hoop Pine	1 in 4 ..	
6. New Zealand White Pine ..	1 in 4 ..	
7. Hoop Pine	1 in 8 ..	} No taint could be detected
8. New Zealand White Pine ..	1 in 8 ..	

These particular samples of hoop pine and New Zealand white pine, when tested in this way, taint to approximately the same extent.

Distillation as described concentrates the tainting substances, and it was desirable to work out a test based on this method which could distinguish samples that were likely to taint. Eventually the following procedure was standardized, and is put forward here as a method that can be readily applied in any laboratory for determining the probable tainting properties of a wood.

4. Laboratory Test for Timber which will Taint Butter.

Five grams of the powdered wood are placed in a distilling flask and 250 c.c. of distilled water added. After thorough mixing, the flask is brought to the boil and 50 c.c. distilled, the distillation time being about

10 minutes. The distillate is mixed and 5 c.c. taken and diluted to 25 c.c. This is poured over the surface of 12 grams of butter uniformly spread on the interior of a 4-in. diameter clock glass. The butter with the overlying diluted distillate is allowed to stand overnight and next morning the surface is washed with water and the excess water taken off by absorbing on filter paper. The butter is then tasted and the odour observed. A timber suitable for butter boxes should impart no more than a barely perceptible odour or flavour to the butter.

Note 1.—The fineness of powdering of the wood does not seem to be critical. No difference could be observed when wood powdered to pass a 40 or 60 mesh sieve, or simply raspings obtained with a fine rasp, were used.

Note 2.—The dilution 5 c.c., made to 25 c.c., is mentioned as it was found suitable in these experiments. A different observer might find some other dilution desirable. Unfortunately, the keenness of the palate is the deciding factor. The worker should try the test on several samples of non-odorous New Zealand white pine or clean non-odorous hoop pine preferably from butter boxes which have not tainted, and decide just what dilution he finds most suitable.

Using the method as described above, 25 samples of "stinker" hoop pine and 23 samples of hoop pine from butter boxes which had tainted the butter, although not strongly smelling, were found to impart definite taints to the test butter. The taints were of quite a different order of intensity to those obtained from 10 samples of New Zealand white pine and 10 samples of hoop pine obtained from non-tainting butter boxes in which either no taint could be detected or it was so faint as to be doubtful.

Twenty samples of *P. radiata* varying from knotty to clean white timber all imparted taint to the butter in varying intensities, but always definite. The taint was strongest in the most knotty and resinous samples. Here it may be noted that several samples of knotty hoop pine did not taint.

5. The Volatile Oils of *P. radiata*.

3,500 grams of air-dry selected knotty and resinous *P. radiata* in the form of sawdust were steam distilled and the first 9 litres obtained extracted with low boiling point petrol ether. On careful evaporation of the petrol ether, 17.5 grams (0.5 per cent. of the wood) of a pale yellow free-flowing oil were obtained having a strong turpentine-like flavour and odour. The determined properties of this oil were as follows:—

Specific Gravity at 18° C.	..	..	0.87.
Specific Rotation	..	..	—16.0°.
Refractive Index	..	..	1.48.
Distillation—77 per cent. distills between	..	..	150° and 200° C.
			Remaining 33 per cent. distills above 200° C.
Solubles in 4 per cent. NaOH	..	..	Trace.
Pinene identified as being present by preparation of the nitrosyl chloride melting point	..	..	103° C.

A sample of clean *P. radiata*, free of knots, treated similarly, gave a yield of 0.05 per cent. of similar oil. The sample had been shown to taint butter.

A minute drop of this oil on a clock glass inverted over butter in another clock glass and allowed to stand overnight imparted a strong odour and

flavour to the butter, typical of that obtained from the wood in practice. The intensity with which the oil taints butter can be judged from the following experiment.

0.05 grams of the oil were thoroughly mixed with 10 grams of butter by working with a spatula. One gram of taint butter was mixed with 9 grams of butter, and this dilution continued four times in all.

The final dilution, containing 5 parts per 1,000,000, was found to be tainted to a degree which would be described as "very strong" in butter grading and would definitely de-grade the butter. Judging by the intensity of taint obtained in this and similar experiments, it appears that wood-tainted butter from boxes of this timber in practice would contain from 1 to 10 parts per million of the tainting oil. Two grains of the oil uniformly distributed throughout a 56 lb. box of butter would impart a strong wood taint to it.

6. The Volatile Oils of Hoop Pine.

5,000 grams of air-dry "stinker" hoop pine which had been shown to taint butter badly were steam distilled and the oils extracted with petroleum ether. The total yield was only 2 grams (0.04 per cent. of the wood). The oil recovered was of an oleo-resinous nature with a comparatively mild aromatic smell quite different from that from *P. radiata*. The flavour was very strong and pungent and, when imparted to butter, similar to that of the naturally tainted butter.

Five parts per million of this oil in butter gave a very faint taint, but with 10 parts per million the taint was quite definite.

The oil was soluble in ether, petroleum ether, alcohol, and, except for a small proportion of insoluble material, in cold 4 per cent. sodium hydroxide solution. It contained a small proportion of some substance giving an intense red colouration with the p. diazobenzene-sulphonic acid reagent of Hanke and Koessler*. Several samples of badly wood-tainted butter from hoop pine boxes were found to give this reaction quite definitely. However, the substance giving the reaction represents but a small proportion of the tainting oil and was found to occur in very variable proportions in samples of the wood which tainted. A definite reaction could not be obtained with some samples of tainted butter and so the test cannot be used as an indication of wood taint independent of taste.

7. The Permeability of Various Wrapping Materials to the Tainting Vapours.

The use of a more impermeable wrapper than the usual vegetable parchment has often been suggested as a preventative of wood taint. Of several tried by the Queensland Wood Taint Committee, tinfoil appeared to be the only one with which there was any certainty of preventing wood taint. Cellophane did not prove quite successful in the Committee's tests, and New Zealand† experiments confirm this. However, several papers have been tested by us in practical experiments using the usual type of butter box made of *P. radiata*. The results of these tests are published in the second paper, and are interesting as they completely confirmed the conclusions drawn from the following simple laboratory experiments.

* Hanke and Koessler. *Jour. Biol. Chem.* 50 : 235, 271. 1922.

† N.Z. *Jour. Agric.* 40 : 406. 1930.

The papers tested were—

Cellophane.—Grades 300, 400 and 1200 waterproof.

Diallux.—A paper similar to cellophane in appearance.

Glassene.

Waxed Parchment.—This paper, described as waxed parchment in the trade, was not really a parchment but a good quality unparchmentized waxed paper.

Vegetable Parchment.—A good quality parchment of the usual type for butter wrapping.

A layer of butter was smeared uniformly over the inside of a 4-in. diameter clock glass. Across this was stretched a sheet of the paper to be tested, and over this was inverted another clock glass of the same size. On the interior of this upper glass a drop of the volatile oil of *P. radiata* was placed. On tasting the butter on the lower glass after 30 hours standing at 12° C., the following results were obtained :—

Cellophane 1200 waterproof	..	..	..	No detectable taint.
Parchment	..	..	..	Definite.
Glassene	..	..	..	Strong.
Diallux	..	..	..	Strong.
Waxed "Parchment"	..	..	..	Very strong.
Cellophane 400	..	..	..	Very strong
Cellophane 300	..	..	..	Very strong.

In the practical experiments with *P. radiata* boxes, cellophane 1200 waterproof was also found to be the only wrapper preventing taint, and the ordinary parchment was more satisfactory than any of the other papers.

Laboratory experiments using the oil from hoop pine gave similar results.

It is interesting to note that the order of permeability to the tainting oily vapours is not necessarily the same as to other gases. For instance, measurements of the rate of diffusion of carbon dioxide through these papers gave the following results :—

Grams of carbon dioxide diffusing through 1 sq. cm. of the paper per minute from an atmosphere of carbon dioxide at a pressure of 2 cm. of water into an atmosphere of carbon dioxide free air under a vacuum of 3 cm. of water, temperature 12° C.—

	Grams × 10 ⁹ .			
Cellophane 1200	2
Cellophane 400	10
Cellophane 300	12
Diallux	12
Parchment	35
Glassene	50
Waxed "Parchment"	35,500

Although parchment was considerably more permeable to CO₂ than cellophane 300 and 400, it is less permeable to the tainting vapours of wood.

Wood Taint in Butter :

Experiments on its Prevention.

By W. J. Wiley, M.Sc.

Summary.

Experiments with various wrapping materials and coatings for the timber of the box with the object of preventing wood taint were made. These indicated that a casein-formalin coating sprayed on the box was at least as efficient as any and considerably cheaper. Experiments were then made with this treatment, using 45 boxes for each series in Adelaide, Sydney, and Brisbane. In Adelaide the treatment completely prevented the de-grading by wood taint of butter by *P. radiata*. The Sydney and Brisbane experiments were with "stinker" hoop pine of different qualities. With these, the treatment caused an improvement, but the Brisbane test showed the improvement was not sufficient to allow of the use of the worst grade of this timber. The Sydney experiment, which used a less severe grade of "stinker" pine, showed that this quality could be satisfactorily used after treatment. Ordinary good quality hoop pine if sprayed, would therefore no doubt be completely free from taint. The experiments are being continued to determine the efficiency of the treatment under actual export conditions.

1. Introduction.

A paper published elsewhere in this Journal shows that the tainting of butter sometimes experienced when hoop pine and *P. radiata* boxes are used is due to the presence, in the wood, of volatile, fat-soluble substances. No practical means of removing these from the wood appears to be satisfactory, and experiments were therefore directed to preventing their access to the butter. This can be accomplished either by wrapping the butter in an impermeable paper or by coating the box with an impermeable varnish or similar type of material. Obviously any practical method must be cheap and free from the danger of imparting a new taint to the butter. Experiments with various grades of parchment, with glassene, cellophane (grade not specified), and tinfoil as wrapping materials were mentioned in the previous article. For the first series of experiments aimed at prevention, it was considered advisable to repeat some of this work, and to test several other possible methods of preventing the taint.

2. First Series of Experiments.

P. radiata was selected as the timber for this test, as it appears inevitably to taint butter if used in the usual way. Although hoop pine has at times caused wood taint, many samples of it do not adversely affect butter. Accordingly, if this timber had been used, there would have been some uncertainty as to the significance of the results. The number of boxes and treatment were as indicated on the next page.

It will be noted that no tests of paraffined boxes were made. The experience of many Australian factories has shown this treatment to be quite ineffective in preventing taint. From the nature of the materials causing taint, this is what might be anticipated.

The boxes were all of the Saranac wire-bound type, and when sprayed, were treated on the inside only in the shook form before being made up into the finished box.

Boxes Treated.

Mark.	Treatment.	No. of Boxes.
<i>A</i>	Sprayed internally with shellac dissolved in borax solution ..	2
<i>B</i>	Sprayed internally with shellac dissolved in alcohol ..	2
<i>C</i>	Sprayed internally with casein dissolved in borax solution and formalin	3
<i>D</i>	Sprayed internally with casein dissolved in caustic soda solution and formalin	3
<i>F</i>	Sprayed internally with aluminium paint, using casein solution as vehicle	2
<i>H</i>	Sprayed internally with metal (tin and aluminium)	3
<i>G</i>	Lined with patent cardboard liners	4
<i>J</i>	Lined with cellophane grade 300	3
<i>K</i>	Lined with cellophane grade 400	3
<i>L</i>	Lined with cellophane grade 1200 waterproof	3
<i>M</i>	Lined with glassene	3
<i>N</i>	Lined with diallux	2
<i>O</i>	Lined with waxed paper	3
<i>P</i>	Lined with 3 sheets usual parchment	2
<i>R</i>	Lined with 5 sheets usual parchment	1
<i>Q</i>	New Zealand white pine box with 3 sheets parchment	2
<i>S</i>	North Queensland kauri pine box with 3 sheets parchment ..	1

Notes on the treatments :—

<i>A.</i>	Shellac	168 grams.
	Borax	42 grams.
	Water	560 c.c.

About 250 grams per box of this strength solution were used. It dried with a flat surface. The odour of the wood could be detected after treatment.

<i>B.</i>	Shellac	168 grams.
	Alcohol	560 c.c.

About 250 grams per box were used. It dried with a glossy surface. The shellacing of butter boxes was practised in the early days of the industry in Australia, when they were much more valuable than now, costing about 4s. 6d. each.

C. Two solutions were used, the casein mixture and a dilute formaldehyde solution.

1. Casein	50 grams.
Borax	7.5 grams.
Water	300 c.c.
2. Formaldehyde 40 per cent.	100 c.c.
Water	1,000 c.c.

After spraying the box with solution 1, it was immediately sprayed with solution 2. Solution 1 is viscous and sinks into the wood very slowly. Immediately solution 2 is applied, the mixture sets to a jelly which dries leaving a hard surface coat on the wood, which has a pleasing varnished appearance. The treatment with formaldehyde is necessary in order to render the coating non-adhesive to wet paper and to prevent the possible growth of moulds on the treated surface. Solution 1 can be used for spraying any time up to about 5 days after preparation.

D. This was used in exactly the same way as *C*, the box being first sprayed with the casein solution and then with formaldehyde.

Casein	50 grams.
Caustic soda	4 grams.
Water	170 c.c.

This was tested because it is possible by using caustic soda in place of borax to obtain a more concentrated solution of casein and still have a reasonable viscosity. The viscosity of the above solution, soon after preparing, was about equal to that of the casein in borax solution, although a much greater proportion of casein is present (22 per cent. as against 14 per cent. in the borax solution). The viscosity, however,

increases on keeping, and after 12 hours the solution would be too thick to spray. It sets to a jelly within 36 hours. Owing to the strong alkalinity, this treatment deepened the colour of the wood.

The casein used in all experiments was prime lactic, i.e., "self-sour" casein.

<i>F.</i>	Casein	..	..	..	..	150 grams.
	Borax	..	..	..	..	22.5 grams.
	Water	..	..	..	..	1,100 c.c.
	Aluminium powder	..	..	..	..	320 grams.

After spraying, this was treated with dilute formaldehyde solution in the same way as *C* and *D*.

H. These metal-sprayed boxes were disappointing in appearance. The metal adhered very irregularly to the wood and showed a strong tendency to fall away as powder. The timber smell could be detected as readily on the treated side of the wood as on the untreated side.

G. These boxes were prepared in accordance with a patent of Mr. Abbey's, Manager of the Co-operative Box Co., Yarraville, Victoria. A sheet of cardboard, lightly waxed, is bound to the inside of the sides, top, and bottom of the box, as it passes through the box-making machine. Separate sheets are used for covering the ends. These boxes were papered with three sheets of parchment before packing.

O. Waxed Parchment.—This was a good quality waxed paper. Three sheets were used, and then two additional sheets of parchment, to prevent the butter coming in contact with the waxed paper.

J, K, L, M, N. These papers were used in place of, and in the same way as, parchment, three sheets being used.

All the sprayed boxes were papered with three sheets of dry parchment*.

The *P. radiata* was kiln dried. It was of good quality, containing no loose knots and averaged about three firm knots to the box. There were no resin pockets in any of the boards.

The boxes were packed with butter on the 22nd April, 1931, kept at 50-60° F. until the 27th, when the butter was graded. They were then placed in cold storage at 10° F. and kept till the 18th June, when they were given their final grading and examination for wood taint. The butter was thus in the boxes 9 weeks.

The results of the final grading may be summarized as follows :—

The New Zealand white pine boxes and kauri pine box had no wood taint. One box of the three *P. radiata* boxes papered with only parchment was wood tainted. The timber must therefore have been particularly good, and definite conclusions cannot be drawn as to the efficiency of any treatment with which no taint was found. Any treatment which allowed wood tainting, however, is obviously to be rejected.

The following boxes showed definite wood taint :—

H, metal sprayed ; *J*, cellophane grade 300 ; *K*, cellophane grade 400 ; *M*, glassene ; *N*, diallux ; and *O*, waxed paper.

The following boxes were not wood tainted :—

A. Sprayed with shellac in borax. This, however, is unsuitable, as the preparation adhered to the parchment where this was wet.

* The parchment used in papering butter boxes is cut in sheets 48 x 12 inches. The usual method of papering is to use two sheets, each of which is folded down one side (or end) of the box across the bottom and up the other side (or end), the two sheets crossing each other at the bottom of the box. When the box is filled, the overlap is folded over the top of the butter, the opposite ends of the sheet meeting in the middle. (The internal measurements of a butter box are approximately 1 foot x 1 foot x 1 foot.) Thus the bottom and top of the box are covered with two thicknesses of paper, and each side and end with one thickness. The edges where the sides and ends of the box meet are exposed. Another method which is coming into favour and is much superior, is to use three sheets of paper. The first sheet is wrapped vertically round the inside of the box covering the sides and ends. The two other sheets are then applied as in the previously described method. Thus sides, ends, top, and bottom of the box all have two thicknesses of parchment and the edges are protected by one thickness. This was the method adopted in all the boxes in this series of experiments. The paper was used dry.

B. Shellac in alcohol. Although not wood tainted, the butter had a foreign taint due to some impurity in the alcohol.

C. Casein in borax.

D. Casein in caustic soda.

F. Aluminium paint using casein vehicle.

G. Patent cardboard lining.

L. Cellophane grade 1200 waterproof.

A and *B* are unsuitable and comparatively expensive. *F* and *L* are also expensive and would cost approximately 6d. per box. In *C* and *D* the materials used are cheap. At current prices they would cost less than $\frac{1}{2}$ d. per box. With mechanical appliances for spraying, the cost of this operation per box should be very small. In a trial on 100 boxes, spraying by hand and with no mechanical appliances for handling, it was found that the cost per box was about $\frac{1}{2}$ d. The total cost of spraying should therefore be in the neighbourhood of $1\frac{1}{2}$ d. per box.

These experiments then indicated that the most promising treatment was with a casein solution. This would be very acceptable to the dairy industry, which could largely increase its output of casein if a ready market were available. It was accordingly decided to give this treatment a more thorough test. The casein in borax rather than in caustic soda solution was chosen, because of its better keeping qualities and absence of discolouration of the wood.

3. Tests in Casein-sprayed Boxes.

A thorough series of tests was arranged in Adelaide, Sydney, and Brisbane, with timbers selected by laboratory tests to give varying degrees of taint if used for butter boxes in the usual way. In all places, the tests were run on similar lines; 47 experimental boxes were used, and arranged thus—

20 boxes marked <i>A</i>	..	Experimental timber sprayed with casein-formalin solution and dry papered with 3 sheets parchment.
10 boxes marked <i>B</i>	..	Experimental timber sprayed with casein-formalin solution and dry papered with 2 sheets parchment.
10 boxes marked <i>C</i>	..	Experimental timber, untreated and papered with 3 sheets of parchment.
5 boxes marked <i>D</i>	..	Experimental timber, untreated and papered with 2 sheets of parchment.
2 boxes marked <i>E</i>	..	New Zealand white pine papered with 3 sheets of parchment. These were used as controls on the keeping quality of the butter.

(i) *Adelaide Experiments.*—Kiln-dried *P. radiata* was used for these tests. The boxes were of the solid type using $\frac{1}{2}$ inch thick top, sides, and bottom, and $\frac{3}{8}$ inch thick ends. Unfortunately, the boxes after being made up had to be knocked to pieces for transport. When again made up, the nails did not hold well, and when packed with butter the sides sprang out from the ends somewhat, exposing the butter there to vapour from the outside of the box. Any wood taint found was therefore probably stronger on the edges than would normally have been the case.

The casein in borax and formaldehyde solutions were of the strength already described. The interior of the box only was sprayed. Approximately 1 lb. of casein solution or 2 oz. of casein and $\frac{1}{8}$ pint of formalin

solution was used per box. If the cost of casein is taken at £25 per ton, borax £22 10s. per ton, and formalin 1s. 6d. per pound, the cost of material in the treatment is approximately 0·68d. per box.

The boxes were marked and papered as already described. They were filled on the 21st August, and kept at about 60° F. until the 25th August, when a few were first graded. They were then stored at about 10° F. until the 28th November, when they were moved ready for grading on the 2nd December. A few boxes were taken out half way through the storage period, but after grading, were returned to cold storage. The butter was thus in the boxes 14 weeks and 5 days.

The final grading was performed independently by three graders who did not know the identity of the boxes graded. The graders were asked to define any wood taint found, as—"faint," "definite," "strong," or "very strong," and to record observations for the top, bottom, sides and ends, and edges of the boxes separately. They also recorded if the taint found was sufficient to de-grade.

The best method of averaging the results appears to be to regard each grader's remarks on each portion of a box as a separate observation, and to record the percentage of the total observations falling in each group (Table 1).

TABLE 1.

—	Top.	Bottom.	Sides and Ends.	Edges.	Percentage of boxes de-graded.
<i>A. Treated boxes with three sheets of parchment—</i>					
No taint ..	81	98	93	36	0
Faint ..	17	2	7	34	
Definite ..	2	0	0	30	
Strong ..	0	0	0	0	
Very strong ..	0	0	0	0	
<i>B. Treated boxes with two- sheets of parchment—</i>					
No taint ..	60	97	80	0	0
Faint ..	37	3	20	24	
Definite ..	3	0	0	40	
Strong ..	0	0	0	33	
Very strong ..	0	0	0	3	
<i>C. Untreated boxes with three sheets of parch- ment—</i>					
No taint ..	60	90	90	17	20
Faint ..	20	10	10	40	
Definite ..	13	0	0	20	
Strong ..	7	0	0	23	
Very strong ..	0	0	0	0	
<i>D. Untreated boxes with two sheets of parchment—</i>					
No taint ..	0	53	40	0	100
Faint ..	20	13	27	0	
Definite ..	33	34	33	33	
Strong ..	47	0	0	33	
Very strong ..	0	0	0	33	

The top surface of one of the control boxes made of New Zealand white pine was definitely wood tainted. The results can be summarized by grouping the observations on top, bottom, sides, ends, and edges, and this has been

done in Table 2. It should be noted, however, that in practice equal weight is not given to taint on these different portions of the box. The edges, which are generally most severely tainted, are of least importance, as they represent such a small proportion of the total contents of the box.

This explains why, although the taint in group *C* appears less than in group *B*, there are more boxes de-graded in group *C*. The taints recorded in group *B* occur largely on the edges.

TABLE 2.

Taint				A. Treated 3 papers	B. Treated 2 papers.	C. Untreated 3 papers.	D. Untreated 2 papers.
Free	..	..	..	77	59	64	23
Taint	..	..	..	15	21	20	15
Definite	..	..	..	8	11	8	33
Strong	..	..	..	0	8	8	20
Very strong	..	..	..	0	1	0	9
Percentage of boxes degraded				0	0	20	100

The results show that butter can be stored three months in boxes made of treated *P. radiata* without any de-grade due to wood taint. They also confirm the value of the third sheet of parchment in protecting against taint. A more thorough trial is being made by the shipment to London of 100 cases of butter in treated *P. radiata* boxes. This shipment is being made by the South Australian Farmers' Union in boxes sprayed by the Division of Forest Products.

These results are highly satisfactory, especially in view of the fact that any taint on the edges was increased owing to the boxes having to be pulled apart and re-nailed. The fact that not a single treated box was de-graded after three months' storage is evidence of the practical efficiency of the process.

(ii) *Brisbane Experiments.*—These were arranged in exactly the same manner as the Adelaide tests, but with the object of testing the efficacy of the casein treatment in preventing taint from "stinker" hoop pine. All the boxes were made from one log which was an extremely bad example of "stinker" pine. Laboratory tests showed that it would taint very strongly, and it was so bad that it would obviously be rejected by any miller for the manufacture of butter boxes. The log was cut into 1-in. boards and seasoned four weeks. These were then cut to $\frac{1}{4}$ inch thickness and made into wire-bound (Saranac) boxes two weeks before filling with butter.

The boxes were sprayed on both sides with the casein and formalin solutions, the same strengths and quantities as previously described being used. The same number of boxes as in the Adelaide experiments were used.

The boxes were packed with butter on the 11th September, and kept at 50–60° until the 16th, when one box of each group was graded. They were then placed in cold storage at about 12° F. until the 9th December, when they were removed and graded on the 11th. A few boxes were removed for grading on the 24th October. At the first grading, five days after packing, the treated box (*A*) with 3 papers had no taint, with 2 papers (*B*) slight taint, and the untreated boxes were badly tainted. At the second grading on the 24th October, the box in group *A* was slightly wood tainted, and in groups *B*, *C*, and *D*, badly tainted. The results of the final grading three

months after packing are given in Table 3. The grading was performed exactly as in Adelaide by three independent graders, and results are averaged as before.

TABLE 3.

—	Top	Bottom.	Sides and Ends.	Edges.	Percentage of boxes de-graded.
A. Treated boxes with three sheets of parchment—					
No taint ..	7	0	0	1	73
Faint ..	38	22	35	44	
Definite ..	27	30	36	36	
Strong ..	22	32	25	13	
Very strong ..	6	16	4	6	
B. Treated boxes with two sheets of parchment—					
No taint ..	0	0	2	0	96
Faint ..	18	8	17	11	
Definite ..	41	29	35	48	
Strong ..	33	41	42	26	
Very strong ..	8	22	4	15	
C. Untreated boxes with three sheets of parchment—					
No taint ..	0	0	0	0	97
Faint ..	3	3	6	3	
Definite ..	23	10	8	10	
Strong ..	27	37	34	37	
Very strong ..	47	50	52	50	
D. Untreated boxes with two sheets of parchment—					
No taint ..	0	0	0	0	100
Faint ..	13	7	8	0	
Definite ..	27	33	12	0	
Strong ..	47	33	48	40	
Very strong ..	13	27	32	60	

One of the two New Zealand white pine boxes was definitely wood tainted and was de-graded by one grader.

The results are summarized as before in Table 4.

TABLE 4.

Taint	A Treated 3 papers.	B Treated 2 papers	C. Untreated 3 papers	D. Untreated 2 papers.
Free	2	1	0	0
Faint	35	14	4	7
Definite	32	38	12	18
Strong	23	35	34	42
Very strong	7	12	50	33
Percentage of boxes de-graded	73	96	97	100

The difference in taint found between the different groups was greater than Tables 3 and 4 indicate. Many of the boxes in group A were graded as having "very faint" taint. These are grouped with "faint" in the tables. Again in groups C and D "very strong" was not considered emphatic

enough by the graders, and many of the results recorded as "very strong" in these groups are more strongly tainted than the "very strong" results in groups A and B.

However, the results definitely show that the treatment was not successful in preventing serious de-grading of the butter packed in such timber. It caused considerable improvement, but not nearly enough. The results are valuable in showing the type of timber it would be futile to attempt to use with this treatment. The test was designed to be especially severe, and the quality of pine was such that under no circumstances would it ever find its way into butter boxes.

(iii) *Sydney Experiments*.—In these tests "stinker" hoop pine was again used. All the boxes were made from one log. The timber was obviously of a quality unsuited for butter boxes, but laboratory tests showed it to be unlikely to impart a severe taint such as that used in the Brisbane tests. The timber was seasoned five weeks in $\frac{3}{4}$ inch thickness and then dressed to $\frac{1}{2}$ inch and $\frac{5}{8}$ inch thickness for making into boxes, and seasoned another week before packing. The boxes were of the solid type.

The boxes were sprayed on both sides as described previously. They were filled on the 18th September, and kept cool until the 24th, when one box of each group was graded. They were then placed in cold storage at 12° F. until the 16th December, when they were removed for grading on the 18th. A few boxes were graded on the 5th November to make sure of the keeping quality of the butter.

The following results were obtained after the three months' storage. Four graders gave their independent grades and these are averaged as before.

TABLE 5.

	Top	Bottom	Sides and Ends.	Edges.	Percentage of boxes de-graded
A. Treated boxes with three sheets of parchment—					
No taint ..	58	88	87	31	1
Faint ..	40	10	13	49	
Definite ..	2	2	0	11	
Strong ..	0	0	0	9	
Very strong ..	0	0	0	0	
B. Treated boxes with two sheets of parchment—					
No taint ..	53	88	78	15	7
Faint ..	42	12	15	50	
Definite ..	5	0	7	28	
Strong ..	0	0	0	7	
Very strong ..	0	0	0	0	
C. Untreated boxes with three sheets of parch- ment—					
No taint ..	50	71	76	29	11
Faint ..	40	29	32	39	
Definite ..	8	0	0	24	
Strong ..	2	0	0	8	
Very strong ..	0	0	0	0	
D. Untreated boxes with two sheets of parchment—					
No taint ..	42	68	74	11	26
Faint ..	53	21	21	42	
Definite ..	0	11	5	31	
Strong ..	5	0	0	11	
Very strong ..	0	0	0	5	

These results are summarized in Table 6.

TABLE 6.

Taint.	A. Treated 3 papers.	B. Treated 2 papers.	C. Untreated 3 papers.	D. Untreated 2 papers.
Free	66	58	54	48
Faint	28	30	35	34
Definite	4	10	8	12
Strong	2	2	3	4
Very strong	0	0	0	2
Percentage of boxes de-graded	1	7	11	26

Both the control boxes of New Zealand white pine were faintly wood tainted, although not sufficiently to de-grade.

The results show that the boxes in group *A* were satisfactory. Only one grader of the four considered the taint in one of the twenty boxes sufficient to de-grade. The graders agreed that the taint was no more than would be obtained from any timber after three months' storage. It will be noted that only a portion of the untreated boxes were de-graded, as compared with the Adelaide tests where all the boxes of group *D* were de-graded. It appears that the treatment, although causing a large improvement in hoop pine, is not so impermeable to its tainting vapours as it is to those from *P. radiata*. However, as the timber used for these Sydney experiments was worse than would be selected from hoop pine for use in butter boxes, and the casein treatment prevented serious taint, the treatment could apparently be relied on to prevent taint from hoop pine of a reasonable quality.

4. Economic Aspects.

The successful development of this process would be of very considerable advantage to the dairy and timber industries. It would mean the utilization of a large quantity of Australian-grown timber to replace the white pine at present imported from New Zealand. This would lead to a considerable saving in the cost of the box. Further, it would result in profitable utilization of a large quantity of casein which at present is run to waste. Considering the export trade alone, it is possible to estimate the value of these savings. In 1931 there were exported approximately three million boxes of butter. For every penny saved by the use of *P. radiata*, this would mean a saving of £12,500 to the dairy industry. The cost of the *P. radiata* box is likely to be about 6d. less, and this would mean a total saving of £75,000 per annum on present export quantities.

The quantity of casein used would be about 375,000 lb. At a value of £25 per ton this would mean the utilization of £4,200 worth of casein. Finally there would be the utilization of approximately 10 million super feet of Australian timber to replace imported pine valued at £150,000.

5. Acknowledgments.

During the course of this work, the Council for Scientific and Industrial Research has been considerably assisted by various people. The work was made possible by a generous grant of £300 from the Australian Dairy Council. In Victoria, the following firms and individuals donated material, or gave assistance in other ways—the Yinnar Butter Factory Pty. Ltd., the Manager

of the Government Cool Stores, the Co-operative Box Co. of Victoria Ltd., Spicer and Detmold Ltd., H. J. Langdon and Co. Pty. Ltd., J. B. Arnold Pty. Ltd., Metal Sprayers Anti-Corrosion Pty. Ltd.; in South Australia—the Woods and Forests Department, and the South Australian Farmers' Union; in New South Wales—the Primary Producers' Union, Messrs. Munro and Lever, sawmillers, Norco Ltd., and the Waterside Cold Stores, Sydney; in Queensland—the Wood Taint Committee, Hancock and Gore Ltd., sawmillers, Mr. Saxelby, manager of Booval Butter Factory, and Professor Bagster, University of Queensland. The Commonwealth Department of Markets graded the butter in all States, and graders of the various State Departments of Agriculture assisted in this important part of the work.

“Pulpy Kidney,” or Acute Infectious Enterotoxaemia of Lambs due to *B. ovitoxicus* (Bennetts).

By D. T. Oxe, B.V.Sc., Veterinary Pathologist, Department of Agriculture, Tasmania.

The investigations reported in the brief article that follows form part of a programme of researches into problems of the pastoral industry being carried out under the Australian Pastoral Research Trust—Empire Marketing Board scheme. (See this Journal, Vol. 4, p. 133, August, 1931.) They are being undertaken in co-operation with the Tasmanian Department of Agriculture, which is providing the part-time services of Mr. Oxe in order that he may carry out and make the detailed arrangements for the actual experiments. Pulpy kidney of lambs occurs not only in Tasmania, but in many other areas of Australia where the pastures are good. The existence of a laboratory at Launceston close to areas where the condition occurs was one of the considerations influencing the decision to carry out the work with Launceston as a base. In most parts of the mainland, outbreaks have occurred so distant from laboratory facilities that investigators have been hampered in their pathological and bacteriological studies. Dr. Bennetts' recent work on infectious enterotoxaemia (braxy-like disease) of sheep in Western Australia, the results of which will shortly be published as the Council's Bulletin No. 57, was strongly suggestive that pulpy kidney might prove to be due to an allied if not the same micro-organism (*B. ovitoxicus*) multiplying within the small intestine of lambs. Dr. Bennetts had already suggested this in departmental communications though the lamb disease is seldom seen in his State. Although the present season has not been favorable in Northern Tasmania for the occurrence of conditions predisposing to the disease, Mr. Oxe has been able to examine a sufficient number of cases for his research studies and has definitely determined the cause to be due to the multiplication within the small intestine of *B. ovitoxicus* and the consequent liberation and absorption of the fatal toxin. In view of the fact that very shortly the lambing season in the Northern Hemisphere will begin, and that there opportunities will occur to follow up the work of Mr. Oxe pending the publication of his full report, it has been deemed advisable to insert in this edition of the Journal the resumé of his work that follows.—Ed.

1. Introduction.

Pulpy kidney is a fatal disease of young lambs which was described by Dr. J. A. Gilruth in the annual reports of the Veterinary Division of the New Zealand Department of Agriculture over thirty years ago, reference to the disease being made by him under the terms “pulpy kidney,” “plethora disease of lambs,” &c. The disease has since been recorded in many other parts of the world, including the mainland of Australia and Tasmania. The condition is characterized by the fact that lambs are found dead after a few hours' sickness. In-coordination of movement, grinding of the teeth, and convulsions are some of the symptoms seen. One of the most marked post mortem lesions is the pulpy degeneration of the kidney in animals which have been dead for some time.

Susceptibility to the Disease.—Young unweaned lambs in forward condition, which are on good improved pasture, are susceptible to the disease. The majority of lambs examined in Tasmania have been ewe lambs. According to Gill (1) both sexes are equally affected before marking. After marking, the proportion of ewe lambs is greater than

wether lambs. It is not clear whether it is on account of the smaller numbers or because they are receiving a smaller amount of milk, that twin lambs are so seldom affected.

According to various authors, the age of susceptibility varies from 2 to 16 weeks. Experience during the Tasmanian investigations is that it varies from 3 to 13 weeks of age. Various breeds may be affected, but particularly those used for early fattening.

2. Experimental Observations.

Examination of naturally occurring cases for the presence of toxin.—Various theories have been held as to the cause of the disease. That most generally accepted for some years was that an over-rich protein diet due to a combined abundant milk supply and good pasture, or pasture and supplementary diet rich in protein was responsible for elaboration of toxins causing a specific action on the kidneys. More recently, experimental evidence points to toxins from the small intestine being responsible for the disease. Gill (2), Bosworth, and Glover (3) have demonstrated such toxins, while Bennetts (4) was of the opinion that the disease might have a similar etiology to that of entero-toxaemia of sheep.

It was decided to concentrate on the examination of the contents of the alimentary tracts for the presence of toxins and, if any were present, to study their nature.

Germ-free Seitz filtrates of the small intestinal contents from five known cases of the disease were found to be highly toxic for experimental animals. This toxin was very potent even if the material was not collected till 24 hours after the death of the lamb. The toxin is not present in the intestine of normal lambs and therefore will not be caused by the multiplication of bacteria after death. In the experiments carried out, the lowest lethal dose, in terms of the original intestinal contents, was for lambs 2.0 cc. (intravenously), and 1.0 cc. (intramuscularly); for guinea pigs 0.05 cc. (intramuscularly); for mice 0.005 cc. (intramuscularly), and 0.0025 cc. (intravenously).

It will thus be seen that the toxin content of the small intestine material was very high.

Keeping Qualities of Toxic Material.—Mixing 0.5 per cent. chloroform to the contents and placing in a small domestic refrigerator made it possible to keep the contents toxic for at least two months without appreciable loss of toxicity.

Neutralization of Natural Toxin by Antiserum.—Toxic filtrates of intestinal contents were neutralized by *B. ovis* antiserum but not by *B. welchii* or *B. oedematis* antisera.

Symptoms in Experimental Animals.—Animals receiving lethal doses of toxin died in from a few minutes to six hours after injections. The time varied according to the route of injections and the size of the dose. The symptoms first noticed in lambs were dullness and depression followed by incoordination of movement, indications of pain, dyspnoea, violent trembling and convulsions, and finally, death. This usually occurred during, or immediately after, a convulsion.

(2) Gill, D. A., *N.Z. Agric. Jour.*, 42: 800. 1931.

(3) Bosworth, T. J., and Glover, D. E., *Nat. Vet. Med. Ass. of G. B. & I.* 48th Ann. Congress Rept.

(4) Bennetts, H. W. In the press.

Post-mortem Examination.—The post-mortem findings in the case of experimental lambs were similar to those of natural cases. The leakage of serous fluids was variable being, in general, much more marked in lambs which had been left for some hours before being examined. There was a clear subcutaneous oedema extending down the leg from the site of injection. The kidneys of lambs examined immediately after death were quite firm, the cortex was rather pale, but the vessels of the medullary rays were very congested and therefore quite obvious microscopically. The vessels of the boundary zone were also markedly congested. If the carcass was left for 6 to 14 hours unopened, there would be marked pulpy degeneration of the kidney. This was not the case if examination were made at once.

Cultural Examination.—As the natural toxin was neutralized by *B. ovitoxicus* antiserum, cultural work was undertaken to isolate this organism if present. Pure toxic cultures of an organism resembling *B. welchii* were obtained and filtrates of this culture were prepared.

Injection of Culture Toxin.—Intramuscular injections of this filtrate into a lamb caused its death in six hours after injection. Post-mortem examination was made ten hours after death. There was marked pulpy degeneration of the kidney while other organs showed lesions found in a typical natural case of the disease. This filtrate was also toxic for mice and guinea-pigs.

Neutralization of Culture Toxin.—Culture toxin was neutralized by *B. ovitoxicus* antiserum but not by *B. welchii* antiserum.

Microscopic Examination of Experimental Lambs.—Although toxic changes occur in the liver and to some extent in the myocardium, the most important lesions occur in the kidney. The convoluted tubules are particularly affected, there being a loss of nuclear staining of their epithelium and degenerative changes in the cytoplasm. This is well marked at the time of death. There is also a marked congestion of the vessels in the boundary zone and medullary rays. Almost complete loss of nuclear staining in the cortex was present in the lamb which had received culture toxin.

These lesions are similar to those found in kidneys from natural cases of the disease.

The Nature of the "Pulpy Kidney" Degeneration.—The pulpy degeneration of the kidney is a post-mortem change, and is apparently due to the specific action of the toxin on the epithelium of the tubules, rendering them susceptible to this peculiar and distinctive post-mortem decomposition.

Preparation of Vaccine.—An anaculture vaccine was prepared and injected into a series of lambs. After a certain period these were tested with the natural toxin from the case from which the strain used in preparation of the vaccine was isolated. The experiment was not very conclusive, but gave some indication that the vaccine protected the lambs against the natural toxin.

Nomenclature.—As a toxin elaborated in the bowel by *B. ovitoxicus* is the cause of the condition, the alternative title name is suggested as one which suitably describes the disease.

3. Conclusion.

Pulpy kidney of lambs is shown to be due to a toxin elaborated in the small intestine by *B. ovitoxicus* (Bennetts). (A more detailed description of the above statements will be made at an early date.)

Sheep Blowfly Investigations.

Experiments on Artificial Baits: Preliminary Note on the Products of Decomposition of Wool Fibre (Keratin).

By Martin R. Freney, B.Sc., Biochemist, Division of Economic Entomology.

For some time past, various authorities in Australia, and notably the State Departments of Agriculture and the Council, have been investigating diverse aspects of the sheep blowfly problem. A recent development in the organization of this work is the establishment, by the two bodies concerned, of a special Blowfly Committee to co-ordinate the activities of the New South Wales Department of Agriculture and of the Council. This Committee consists of Dr. J. A. Gilruth (Chairman) and Dr. R. J. Tillyard, representing the Council; and Dr. H. R. Seddon and Mr. W. B. Gurney, representing the Department. Dr. J. M. Mackerras acts as Secretary. The Committee has already held several meetings and has decided to prepare a comprehensive report dealing with the existing state of knowledge of the blowfly problem and the scope of present and future investigations. It is proposed to publish this report at a comparatively early date. The results of the work dealt with in the note that follows have been considered by the Committee, which has also recommended their publication.—En.

Foreword.

By Dr. R. J. Tillyard, D.Sc., F.R.S., &c., Chief, Division of Economic Entomology.

The experiment by Mr. M. R. Freney recorded in the accompanying note is of interest from two points of view, one being the question of sheep susceptibility and the other the influence of trapping in reducing the pest. As regards susceptibility, Mr. Freney's results indicate one method whereby a decomposition product of wool becomes attractive to blowflies and so bears closely on the general problem of susceptibility. As regards the question of trapping, which is at present being extensively studied by the Division of Economic Entomology, it is important to bear in mind that, under normal conditions, the hairy maggot flies or secondary flies are not capable of initiating strike in sheep and that their larvae are enemies of the smooth maggots which do initiate strike. All baits tested so far are found to attract more female flies than males. But the ordinary baits in use, such as liver, offal, or blowfly "soup," tend rather to attract secondary flies in preference to primary ones. A trap and bait which reduces the comparative number of secondary flies and so favours the primary species cannot be scientifically regarded as of any value at all, but rather as a danger. The new bait discovered by Mr. Freney, viz., a solution of keratin in sodium sulphide, approaches nearer than anything yet discovered to the desired end. It must be emphasized that the experiment was designed purely as a qualitative one, not a quantitative one, and therefore the actual numbers caught are of minor significance compared with the proportions of primary and secondary flies in the total catch. Much more work has to be done before it can be asserted definitely that this new bait is superior to those in general use; but, in the meantime, the publication of the note will serve to bring to the notice of pastoralists and others interested the fact that progress is being made in the attempt to evolve an ideal bait in an ideal type of trap.

1. Introduction.

During investigations on the responses of blowflies to chemical substances, it was found that an attractive medium resulted when wool fibre was decomposed by a solution of sodium sulphide. The fibre was obtained by extraction of raw wool with ether and alcohol, and then washing the extracted material with warm water. The wool fat, suint, dirt, and other extraneous material were removed in this way, and the wool fibre obtained as a final product may be considered as consisting largely of the protein keratin. This was hydrolysed with sodium sulphide.

In the preliminary experiments, the provision of an attractive medium was the sole object, and the period and conditions of hydrolysis were not determined.

A small quantity of decomposed keratin (less than 5 grams) kept moist on cotton wool was used as a bait in experimental traps. For comparison, traps baited with 50 grams of fresh sheep's brain, which has been proved in this laboratory to be a much more attractive bait than liver, were exposed simultaneously. On the first day's exposure of the keratin mixture, large catches were recorded, and oviposition occurred on and around the bait. Numbers of small maggots were then present on the bait in most experiments. After the first day, smaller catches were successively recorded.

2. Results.

In the catches recorded, the species of flies caught were determined, and also the sex of the *Calliphora* and *Chrysomya* trapped. These differences are set out in the following table:—

No	Bait	Primary Blowflies								Secondary Blowflies				Total Blowflies caught.
		<i>Calliphora stygia</i>		<i>Calliphora vicina</i>		<i>Lucilia cuprina</i>	<i>Lucilia sericata</i>	% Females	% Primary Blowflies in Whole Catch	<i>Chrysomya rufifacies</i>		<i>Microcalliphora rarisipes</i>	% Secondary Blowflies in Whole Catch	
		F	M	F	M					F	M			
A.	Brain ..	7	7	302	52	12	3	84 ⁰ ₂	45 ⁰ ₂	190	158	191	55 ⁰ ₂	982
B.	Keratin Mixture .	3	0	227	1	1	3	99·5	81	41	5	8	19	289
C.	Total catches of seven traps baited with Keratin Mixture ..	21	5	825	13	13	14	98	86	118	7	21	14	1,037

Note.—F. denotes female. M. denotes male.

A and B were catches made by traps placed a few feet apart and exposed for 48 hours. After this period, the brain had been completely devoured by maggots, and the trap so baited caught no more flies. In some experiments included in the seven recorded under C, it was found that the keratin mixture could retain some degree of attractiveness for six or seven days.

It should be made clear that no useful quantitative comparison can be made between the catches of brain and keratin mixture recorded in the table. However, when the flies in the respective catches were identified, it was found from the proportions of each species and of females present, that significant differences in the attractiveness of the baits existed.

The species most largely represented in the catches is the brown blowfly, *Calliphora augur*, but the brain attracts a larger number of the green, hairy maggot blowfly, *Chrysomya rufifacies*, than does the keratin mixture.

From the table, it is seen that whereas when brain is used about 12% of the *C. augur* caught are males, the figure for the keratin mixture is less than 2%. Over 30% of the *Ch. rufifacies* caught by brain are males, whilst the keratin mixture catches only 6% males of this genus. In view of the damage done to sheep by primary blowflies, it is of interest to note that the keratin mixture is more attractive to these than to secondary blowflies. Besides the flies mentioned above, those trapped included *Peronia rostrata*, *Sarcophaga* spp. and various Muscids.

Recent experiments suggest that hydrolysis of keratin by substances other than sulphides may provide attractive media for flies. A chemical investigation of decomposed keratin, with a view to the isolation and identification of the substances attractive to blowflies, is in progress.

The traps used in this work were recently designed by Dr. A. J. Nicholson.

3. Conclusions.

1. Keratin from wool fibre when decomposed by sodium sulphide solution is attractive to flies.
 2. A higher proportion of females (about 98%) is caught by this bait than by a carrion bait.
 3. The solution containing decomposed keratin is more attractive to primary than to secondary blowflies.
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Parasitological Field Trials with Sheep.

Results at "Gundowringa," New South Wales, and "Frodsley," Tasmania.

By I. Clunies Ross, D.V.Sc., and N. P. Graham, B.V.Sc.

During 1931, field trials were initiated by the Division of Animal Health to investigate different aspects of the problems involved in controlling losses from internal parasites of sheep. This work forms part of the programme that is being undertaken by the Division under the Australian Pastoral Research Trust—Empire Marketing Board scheme (see this *Journal* August, 1931, p. 134). The trials themselves were carried out with the kind co-operation of Mr. D. E. Donkin, of "Meteor Downs," Springsure, Queensland; Mr. C. E. Prell, of "Gundowringa," New South Wales; and Mr. K. Brodribb, of "Frodsley," Tasmania, all of whom very greatly facilitated the experiments by supplying the use of the necessary land and experimental sheep. In addition, the Council desires to record its gratitude for the provision of wire, wire-netting droppers, &c., by the following firms:—The Broken Hill Pty. Co. Ltd., Lysaght Bros. & Co. Ltd., and Corkscrew Steel Fences Ltd. A report on the work at "Meteor Downs" was published in the previous issue (November, 1931). Reports on the work at "Gundowringa" and "Frodsley" are given below.—Ed.

I. Experiments at "Gundowringa," New South Wales.

1. Introduction.

This property is situated on the Southern Tablelands, between Goulburn and Crookwell, at an altitude of about 3,000 feet, the rainfall being approximately 28 inches. The property, which comprises 7,000 acres, is very highly improved, the pastures consisting largely of subterranean clover with an admixture of introduced grasses (Italian rye, cocksfoot, &c.), and being regularly top-dressed with superphosphate each alternate year.

The object of this trial was to investigate the effect, from the point of view of internal parasite infestation, of heavy stocking on improved pastures, i.e., whether (a) the danger of infestation is increased by the greater number of animals grazed, or (b) the danger is actually decreased owing to the improved nutrition of the animals resulting in an increased resistance. At the present time, there is considerable difference of opinion as to which of these effects (a) or (b) is more likely to occur. Further, it was hoped to demonstrate whether any adverse effects could be diminished by heavily stocking paddocks with sheep for a short time and then leaving such areas unstocked for a period of three months to allow infestation of the pastures to diminish, and, in addition, whether in such cases the sheep made better growth owing to the improved conditions of the pastures.

On "Gundowringa," heavy mixed infestations may be met with in lambs at weaning time, the more important parasites being the large stomach worm (*Haemonchus contortus*), the medium stomach worm (*Ostertagia circumcincta*), the small stomach and intestinal worm (*Trichostrongylus* spp.), and the thin-necked intestinal worm

(*Nematodirus* spp.), as well as the large bowel parasites (*Oesophagostomum venulosum* and *Chabertia ovina*). In addition, the large lung worm, *Dictyocaulus filaria*, is not uncommon. The liver fluke (*Fasciola hepatica*), which formerly was common, has now been largely eradicated by repeated drenching with carbon tetrachloride. Such drenching has been adopted as a control measure against stomach worms as well as the fluke.

Five groups of 50 lambs each were employed in the test. They were all of the same breed, Corriedale-Merino cross, and as near as possible of the same condition and age, namely, six to seven months. They had been twice drenched with carbon tetrachloride some time previously.

Lot 1. On improved natural pasture in one paddock at the rate of 1 sheep per acre.

Lot 2. On improved pasture in one paddock at $2\frac{1}{2}$ sheep per acre, without medicinal treatment.

Lot 3. On improved pasture in one paddock at $2\frac{1}{2}$ sheep per acre, the sheep treated each month with carbon tetrachloride.

Lot 4. On improved pasture, subdivided into four paddocks, on each of which sheep were run for one month at the rate of ten sheep per acre, each paddock then being left unstocked for three months. The average stocking was therefore $2\frac{1}{2}$ sheep per acre.

Lot 5. Same as lot 4, but the sheep treated each month with carbon tetrachloride.

All sheep were weighed at monthly intervals throughout the trial, while faeces from five sheep in each group were cultured each month to determine the degree and type of parasitism.

At the beginning of the trial, a number of lambs, of the same age and lot as those from among which the experimental sheep were taken, were examined post-mortem. It was found that these showed the following infestations:—

Haemonchus contortus—light to moderate;

Ostertagia spp.—moderate;

Trichostrongylus spp.—moderate;

Nematodirus spp.—moderate;

Oesophagostomum venulosum—light to moderate;

Chabertia ovina—light; and

Dictyocaulus filaria—a few of the large lung worms were present in all sheep examined, but in no case were they in sufficient numbers to cause ill effects.

2. Course of Trial.

The trial was begun on 26th March, 1931, at which time the average weights were as follows:—

Lot 1.—58 lb. 8 oz.

Lot 2.—57 lb. 8 oz.

Lot 3.—57 lb. 7 oz.

Lot 4.—55 lb. 4 oz.

Lot 5.—55 lb. 8 oz.

The experiments were discontinued on 26th October, i.e., after a period of seven months. All sheep continued in good condition throughout the trial, the four lots on improved pasture making much more rapid gains each month than those on natural pasture, with the exception of September, when, apparently taking advantage of the spring shoot and their greater range of pasture, Lot 1 made a greater gain than any other. In October, the last month, however, this lot actually lost an average of 1 lb. per head, while Lots 2 and 3 gained respectively 4 lb. 8 oz. and 2 lb. 13 oz. per head, and Lots 4 and 5 11 lb. 12 oz. and 9 lb. 9 oz. respectively.

Worm infestations throughout the trial were relatively light in all lots, and did not appear to interfere appreciably with the progress of any lot, unless the loss of weight in Lot 1 in October was due in some measure to this cause.

All sheep were weighed and then shorn on 23rd and 24th October, when the following weights were obtained (average):—

Lot	Wool Cut Per Head		Live Weight Per Head		Gain in Live Weight Throughout Trial
	lb. oz.		lb. oz.		lb. oz.
1	9	8	85	11	27 3
2	11	2	101	10	44 2
3	11	0	100	2	42 11
4	11	2	109	10	54 6
5	11	4	111	1	55 9

3. Discussion of Results.

It is evident that, under the conditions obtaining throughout this trial, so far from any harmful effects accruing from running $2\frac{1}{2}$ sheep per acre on improved pastures compared with one sheep per acre on unimproved natural pasture, all sheep on improved pasture cut more wool per head and showed better gains in weight than those on natural pasture. However, it should be mentioned here that the latter pasture was considerably better in quality than the surrounding natural pasture, owing to the fact that a large part had been used as a sheep camp for very many years, and during that period had, of course, undergone considerable improvement thereby.

So little effect had worm infestation on the sheep on improved pasture that medicinal treatment appeared to have little importance, there being nothing to choose between treated and untreated groups. (It must be remembered that all, however, had been treated twice before the beginning of the trial with carbon tetrachloride for internal parasites, and were seven months old at this time. Moreover, at the end of March, when the trial was begun, low temperatures (down to 0°C) may be encountered at night, so that little further infestations would be expected until the following spring.) As evidence of the relatively low degree of parasitism, no mortality occurred in any group.

Apart from the extraordinary general progress of all lots on improved pasture, that of Lots 4 and 5, which were grazed in rotation on each of four small paddocks for one month, which were then left vacant for three months, is noteworthy, these lots showing slight, but appreciably, greater increases in weight after the first month than Lots 2 and 3, not so rotated. In addition, it was found that, at the end of the trial, those units of pasture in Lots 4 and 5 not having been stocked during the last month showed a very much better growth of clover and grasses than that in Lots 2 and 3, which were rather closely grazed. It was also possible to cut two paddocks of Lots 4 and 5 for silage, these yielding up to 8 tons per acre of green feed.

4. Summary of Results.

1. Under conditions obtaining throughout this trial, it appeared that increased risk of parasitism, owing to heavy stocking on improved pasture, was more than offset by the improved condition of sheep run on such pastures.

2. Sheep run on un-top-dressed natural pasture produced 9 lb. 8 oz. of wool and gained 27 lb. 3 oz. in live-weight per acre, whereas—

(a) sheep run on improved pasture without rotation, at $2\frac{1}{2}$ sheep per acre produced up to 27 lb. 13 oz. of wool per acre and made gains of up to 110 lb. 10 oz. in live-weight per acre; and

(b) sheep run on improved pasture subdivided for monthly rotation through each of four units produced 28 lb. 2 oz. of wool per acre, and made gains of 138 lb. 14 oz. in live-weight per acre.

3. In addition to greater gain in body-weight of sheep rotated on improved paddocks, some of these pastures were cut for silage at the end of the trial, whereas those grazed continuously were eaten well down.

4. Medicinal treatment against internal parasites produced no demonstrable effects in treated sheep in comparison with untreated sheep under the same conditions on improved pasture.

5. At the end of the trial, practically all worm infestation appeared to have been thrown off by sheep on improved pastures, whether the animals had been treated or untreated.

II. Experiments at "Frodsley," Tasmania.

1. Introduction.

This property, situated in the East Coast District of Tasmania, is 5,000 acres in extent, and carries up to 5,000 crossbred sheep. The average rainfall is about 27 inches, of which the greater part falls in the winter, which is severe. The most serious worm infestations at the present time are with small *Trichostrongyles*, (*Ostertagia* spp., *Trichostrongylus* spp, and *Nematodirus* spp.), while heavy infestations with *Oesophagostomum venulosum* and *Chabertia ovina* are not uncommon. According to the Chief Veterinary Officer of Tasmania, Mr.

T. Philp, *Haemonchus contortus* was formerly of major importance, but it appears to have been controlled, but not eradicated, by drenching first with sodium arsenite and copper sulphate, and for the last three years with carbon tetrachloride. As the result of the latter treatment, fluke infestation, which was previously common, has practically disappeared.

The average wool production on this property is very low, for the last year being under 6 lb. per head.

The object of the trial was to determine:—

- (a) Whether standard methods of anthelmintic treatment will diminish losses from small Trichostrongyles, this at present being open to doubt.
- (b) Whether the measure of control effected will lower mortality and lead to any increase in wool production.
- (c) Whether the administration of drugs in a lick will have any effect on controlling infestation with large bowel parasites; and
- (d) Whether the use of nutritional supplements in the form of crushed oats without medicinal treatment will produce results comparable or even better than those obtained by drenching.

Six groups of sheep were included in the trial, three of these consisting of 40 lambs each, two of 50, and one of 97. All lambs were $6\frac{1}{2}$ to $7\frac{1}{2}$ months old crossbreds, and a basal phosphatic lick consisting of salt 50 parts, and dicalcic phosphate 50 parts, was available to all lots.

Lot 1. Drenched monthly with 50 ccs. 1% copper sulphate solution (0.5 gm. of sulphate).

Lot 2. Dosed monthly with sodium arsenite, 0.075 gm., and copper sulphate, 0.3 gm., for the first four months, and then with 0.1 gm. and 0.4 gm. respectively. These drugs were administered in powder form in a spoon specially prepared by the Department of Veterinary Education and Research, South Africa.

Lot 3. Drenched monthly with carbon tetrachloride, 2 cc., in 3 cc. liquid paraffin, and to the lick of this lot was added also sodium arsenite, 1 part, and copper sulphate, 4 parts, per thousand.

Lot 4. Drenched monthly in the same manner as Lot 3, but received no medicinal supplements in the lick.

Lot 5. Received no treatment.

Lot 6. Received no treatment, but, from the beginning of the trial was hand-fed with $\frac{1}{2}$ lb. crushed oats, the average consumption being $\frac{1}{2}$ lb. per head per day.

Each group was retained in a single paddock throughout the trial, the size of the various groups being determined so as to secure as nearly as possible identical grazing conditions.

Lots 1 to 5 were of very similar weight and condition at the beginning of the trial, but those in Lot 6 were mainly "cull" lambs in poorer condition. All sheep were weighed before the trial, and at monthly intervals throughout.

2. Course of Trial.

The trial was begun on 8th April, 1931, and discontinued on 23rd November, 1931. On 8th April the weights were as follows (average):—

Lot 1.—	39 lb.	4 oz.
Lot 2.—	40 lb.	0 oz.
Lot 3.—	40 lb.	7 oz.
Lot 4.—	39 lb.	12 oz.
Lot 5.—	39 lb.	7 oz.
Lot 6.—	35 lb.	13 oz.

During the first four months of the trial, seasonal conditions became progressively worse, cold weather with heavy rains setting in during May and continuing throughout. It was found at the beginning of August, that all sheep in the first five lots were suffering the effects of feed shortage, and paddocks were almost eaten out, that of Lot 4 being particularly bad.

At this time, the changes in weights from the beginning of the trial were as follows:—

Lot 1	gained	5 lb.	14 oz.
Lot 2	„	2 lb.	3 oz.
Lot 3	„	1 lb.	6 oz.
Lot 4	lost	0 lb.	9 oz.
Lot 5	„	2 lb.	1 oz.
Lot 6	gained	4 lb.	4 oz.

Lot 5 was very much the worst of all lots, and at this time four lambs from it had died, as compared with 1 in Lot 1, 1 in Lot 2, 0 in Lot 3, 2 in Lot 4, and 1 in Lot 6.

It was now considered necessary to hand-feed Lots 1 to 5 on oats, as had been done in the case of Lot 6 for the previous four months, a half-pound per head being allowed from this date onward. At the same time, an additional protein supplement in the form of blood meal was added to the basal phosphatic lick of Lot 6 from the 12th August, 50 parts of blood meal added to 50 parts of lick.

At the September weighing, the total losses were found to be:—

Lot 1.—3 sheep (two deaths occurred in the yards shortly after drenching);

Lot 2.—3 sheep;

Lot 3.—1 sheep;

Lot 4.—3 sheep;

Lot 5. -14 sheep; and

Lot 6 was not weighed or counted on this occasion.

All lots showed slight gains in weight.

In October, the total losses in the various lots were:—

Lot 1.—3 sheep;

Lot 2.—3 sheep;

Lot 3.—2 sheep;

Lot 4.—3 sheep;

Lot 5.—16 sheep; and

Lot 6.—7 sheep (one additional death from accident not included).

The sheep received the seventh and last drenching on 8th November, but were not weighed until shorn on 23rd and 24th November. No further deaths had taken place at this time.

At the time of shearing, the weights were:—

Lot	No. of Sheep	Wool Cut Per Head	Live Weight Per Head.	Gain in Live Weight Throughout Trial.
		lb. oz.	lb. oz.	lb. oz.
1	..	4 14	54 13	15 7
2	..	4 2	55 9	15 9
3	..	4 10	58 14	18 7
4	..	3 14	52 8	12 12
5	..	3 5	47 1	7 10
6	..	4 6	50 3	14 6

At the end of the trial, the paddocks of Lots 1, 2, and 5 were approximately equal in condition, that of Lot 3 was definitely somewhat better, and that of Lot 4 by far the worst of all. Sheep in Lot 5 were in much worse condition than the others, many of them losing their wool.

In both Lots 5 and 6, it was found that, while many of the sheep were well grown and comparable to those in any of the other lots, a large proportion were stunted and undersized. Thus, while in Lots 1, 2, 3, and 4 no sheep weighed under 40 lb., in Lot 5 there were 5 out of 34, and in Lot 6, 13 out of 84 beneath this weight. It is obvious, however, from the average weights given, that in no case were the sheep in any group well grown for their ages (14 months), nor did they produce adequate quantities of wool.

In regard to the consumption of medicated lick by Lot 3, this was negligible for the first four months, but during the fifth month this lot consumed 3 gms. per day, during the sixth month 7 gms. per day, and during the seventh month 5 gms. per day per head.

From the 12th August, Lot 6 consumed per head an average of 6.86 gms. of a lick containing 50% blood meal, or approximately 3.4 gms. per day per head of this supplement—too small an amount to exert any marked effect on the nutrition of the animals.

3. Post-mortem Findings.

Five sheep in each of Lots 1, 2, 3, and 4 were killed at the end of the trial, and all helminths (worms) present collected. Unfortunately, through an error, all but two sheep in Lot 5 were drenched with carbon tetrachloride and so only these two were killed. In Lot 6, all animals were drenched, but two were killed subsequently to determine the degree of infestation in the large bowel.

Light infestations with *Haemonchus contortus* were found in 1 out of 5 animals examined in Lot 1, in 1 out of 5 animals examined in

Lot 2, in none out of 5 animals examined in Lot 3, in 4 out of 5 animals examined in Lot 4, and in 2 out of 2 animals examined in Lot 5.

Variable degrees of infestation with small *Trichostrongyles* in the abomusum and small intestine were found in all sheep.

All large bowel parasites were collected and counted, the average number of *Oesophagostomum venulosum* and *Chabertia ovina* per sheep being:—

- Lot 1.—74;
- Lot 2.—87;
- Lot 3.—9;
- Lot 4.—75;
- Lot 5.—36 (two animals only); and
- Lot 6.—45 (two animals only).

4. Discussion.

Though very adverse seasonal conditions interfered markedly with the trial and resulted in marked feed shortage, nevertheless certain definite indications may be drawn from the trial.

(a) *Mortality Rate*.—The mortality rate in each of Lots 1 to 4 was respectively 7%, 7%, 5%, and 6%, while in Lot 5, the untreated control, it was 32%, and in Lot 6 (hand-fed throughout), it was again about 7%. It appears, therefore, that medicinal treatment with any one of three standard methods of treatment reduced mortality from 32% to from 5 to 7%, although the major infestation was with small *Trichostrongyles*. In the case of Lot 6, it appears that hand-feeding alone was able to effect a reduction in mortality comparable to that resulting from medicinal treatment.

(b) *Wool and Mutton Production*.—In addition to markedly lowering mortality, all treated lots showed considerably greater gains in body weight than did Lot 5, this being greatest in Lot 3, and least in Lot 4. Lot 6 showed much greater gains in weight also than did Lot 5, and even than Lot 4, but less than the other treated lots. It should again be mentioned that Lot 4 was handicapped owing to the excessively poor conditions in this paddock. The treated lots showed a gain of $\frac{1}{2}$ to $1\frac{1}{2}$ lb. of wool per head more than the control Lot 5, but it is noteworthy that Lot 6 was comparable in this respect to any of the treated lots, and better than Lot 4.

(c) *Effect in Controlling Large Bowel Parasites*.—There is some suggestion that the administration of sodium arsenite and copper sulphate in licks to Lot 3 had some effect in diminishing infestation with *Oesophagostomum venulosum* and *Chabertia ovina*. However, it is not safe to draw definite conclusions in regard to this, since individual variation may have accounted for the finding of 9 per head in this lot, compared with 74, 87, and 75 per head in the other treated lots. It would be the more remarkable if this finding were a true reflex of the degree of infestation in Lot 3, in view of the fact that this lot only consumed appreciable quantities of the lick during the last three months. This point will be investigated further, since under controlled laboratory conditions, such favorable indications had not been obtained by us.

(d) *Effect of Improved Nutrition from Hand-feeding.*—Though hand-feeding without treatment, in the case of Lot 6, reduced the mortality rate to a degree comparable to that achieved by treatment, and also resulted in similar gains in wool and weight, it cannot be said to have justified itself as an economic alternative to treatment. The cost of the oats consumed during the four months in which this lot received hand-feeding before the other lots would be in the nature of at least 2s. per head, while to this must be added the cost of the blood meal supplement consumed, slight though this was. In comparison with this expenditure of over 2s. per head, the cost of any individual anthelmintic treatment for the whole seven months would not exceed 2d. per sheep.

5. *Conclusions.*

1. Routine monthly treatment with copper sulphate, sodium arsenite and copper sulphate, or carbon tetrachloride alone, greatly decreased mortality caused primarily by small *Trichostrongyles*, though no suggestion was obtained that eradication could be achieved by such measures.

2. Treated sheep cut from $\frac{1}{2}$ to $1\frac{1}{2}$ lb. of wool per head more than untreated, and showed much greater gain in weight.

3. While the administration of certain drugs in the form of licks appeared to lessen the degree of infestation with large bowel worms, this requires confirmation before any opinion is formed.

4. Feeding nutritional supplements without medicinal treatment, though lowering the mortality rate markedly, cannot be justified as an alternative to treatment, because of the very much greater expenditure involved.

5. A combination of improved nutrition with medicinal treatment appears necessary before wool and mutton production on this property can be raised to satisfactory levels.

The Export of Australian Apples.

Suggested Improvements of Present Methods.

By W. M. Carne, Senior Plant Pathologist, Division of Plant Industry.

Mr. Carne was one of the first officers appointed by the Council with a view to the establishment of the Division of Plant Industry. Prior to that, he was a member of the staff of the Western Australian Department of Agriculture. Since joining the Council some four years ago, he has remained in Western Australia, and has given a considerable amount of attention to the problems connected with the export fruit trade, and particularly in regard to the non-parasitic conditions (bitter pit, water core, &c.) that arise during the cold storage and transport of apples. Many of the results of this work have already been published (see this Council's Bulletin 41, and its *Journal* 2 : 49, 1929. 3 : 167, 193, 1930. 4 : 65, 1931).

Early in 1931, as a result of a grant from the Empire Marketing Board, arrangements were made for him to visit Great Britain in order to make himself more conversant with the problems of the fruit export trade at the English end, and also with the investigations of the British Food Investigation Board and other research stations, such as the Horticultural Research Station at Long Ashton. He sailed from Australia on the 26th March and returned via South Africa some months later, finally reaching Perth on the 1st October. In the case of some apples, he was able to follow them from the orchards at blossom time until they had been held on the English markets for some three weeks or more. This experience was of considerable value, as it enabled him to correlate the final condition of the fruit at the marketing end with the treatment it had been given in the orchard and on the Australian wharves.

As a result of his visit, Mr. Carne has come back with some definite ideas as to various ways in which the Australian fruit export trade may be improved. It has been thought that some good would result if these were considered and discussed by growers, packers, and others financially interested in that trade. Through the kind co-operation of the various State Departments of Agriculture and others, arrangements have accordingly been made for Mr. Carne to visit the apple-growing States during the early part of the year 1932, and to discuss his views in person. In the meantime, he has prepared a brief statement of his ideas, which has now been printed below, in order that it might be circulated amongst those interested prior to Mr. Carne's visit.

In so making it available, the Council desires to point out that the article merely forms a basis of discussion and that it should not be construed as being a final statement of the position.—Ed.

1. Introduction.

Australia grows very excellent export apples. In 1931, as in other years, there were no better apples on the London markets from April to July than some from Australia, yet in 1931, as in other years, there were no worse apples on the same markets than some from Australia. The Australian fruit competes with apples from New Zealand and the United States, and to a lesser extent with those from South Africa and Chili.

New Zealand apples are of the same season and of the same varieties as Australian. They have a high reputation for condition,* quality,* and pack; their grading is effective and the grades very uniform; and the range of prices between the highest and the lowest is relatively small. They secure the cream of the market during the season. United States apples have a high reputation for condition, in spite of the fact that they have been held in cool store months longer than those from Australia and New Zealand. That fact operates against their quality, especially their freshness.

* For a definition of these terms see section "The Correct Time of Picking for Export," p. 42.

Their grading is excellent and the pack extremely good. Their good condition despite their long storage is connected with the fact that they are selected from long-keeping winter varieties. Apples from the Southern Hemisphere are of early to late mid-season varieties for the most part, and have shorter storage lives.

South African apples are of varieties common in Australia. Though initially inferior to Australian in quality, they arrive on the markets in better average condition. Chilean apples are also inferior in quality to Australian, but they reach the English markets in good average condition.

The outstanding characteristics of Australian apples on the overseas markets are variability and unreliability. Their condition ranges from very bad to very good, their quality from fair to excellent. Their grading does not result in there being a relation between the grades and the prices received on the same market, i.e., fruit in the top grade often does not obtain as high a price as that in a lower grade. Two types of boxes are used and these vary considerably in quality and suitability. The packing is also variable and ranges from loose packs of badly sized fruit to packs that are in every way satisfactory. The prices received are also variable, and show a range between highest and lowest much greater than those received by competing countries. These facts have set up a reputation which reacts unfavorably on good fruit.

It is perhaps incorrect to speak of the reputation of "Australian" apples. Those from the different exporting States differ so much in average condition and quality, in varieties, and general characteristics, that the fruit trade in Great Britain and on the Continent recognizes definite, though unformulated and unofficial, State standards. It is accustomed to say that one State is above or another below its usual standard in any particular season.

Other defects in the exporting of Australian apples include a multiplicity of brands and marks, an extraordinary number of varieties, far too many small lines, and a lack of a central body set up by the industry and having the power to place shipments in store during temporary gluts, to divert shipments to more favorable markets, and generally to see that the fruit is marketed in the best possible way. The consequences of this lack are irregularly supplied markets, and shortages followed by gluts, during which, besides the resultant poor prices, fruit is necessarily delayed in distribution and deteriorates in consequence.

The growing criticism of Australian apples in recent years is the result, not of their deterioration, but of their condition, packing, &c., not having kept up with the improvement of the fruit from competing countries. Fruit is judged by comparison. New Zealand apples have a reputation much superior to that of those from Australia and average definitely higher prices. It is a useful sidelight on these facts that retail shopkeepers in London rarely label apples "Australian" though "New Zealand" is often seen. Yet both countries distribute appropriate window tickets to retailers.

2. Causes of the Present Conditions of the Export Trade.

The reasons for the lack of standardization and the unreliability of Australian apples may be discussed under the following headings:—

- (i) The present export regulations and their application.
- (ii) Inadequate organization in the industry for the better handling, shipment, and marketing of its fruit.

(iii) Lack of appreciation of the importance of details when marketing fruit overseas.

(i) *Export Regulations*.—Of the regulations in so far as they affect grading the difficulty, as already mentioned, is to design a set of grading rules that will result in apples graded in Australia maintaining their grades when marketed some weeks later in Great Britain. No system of grading will absolutely control condition on the overseas markets because of the varying conditions to which fruit is subjected at sea and after unloading. This makes it all the more important that the condition of the fruit when shipped should be good, especially in the higher grades.

(ii) *Organization in the Industry*.—Inadequate organization in the industry is responsible for many defects which are more or less successfully avoided or overcome by the highly organized competing industries of South Africa, New Zealand, and United States of America. Marked improvement in ships' stowage and refrigeration; handling and marketing overseas; pre-cooling; and to some extent improvement in handling between orchard and ship's side in Australia will come only when the industry decides to organize more effectively for improvement. The best results are likely only when the industry retains control of its product up to the first sale overseas. There is no doubt whatever that the success of our competitors must be largely traced to organization. Better organization in the marketing of Australian apples would be welcomed in New Zealand and South Africa, as the present conditions in the Australian export trade react unfavourably on their marketing as well as on ours.

(iii) *Market Requirements*.—Carelessness and/or ignorance of details is more the concern of individuals (growers, pickers, packers, &c.), and it is to them that this article is particularly addressed. They determine largely the condition, quality, and pack of the fruit before it is shipped. The remedy of defects in these matters lies in their hands through the improvement of present practices of picking, grading, sizing, packing, and labelling.

3. The Correct Time of Picking for Export

Correct picking is essential for both condition and quality. Condition may be defined as freedom from defects which bring about deterioration.

Quality refers mainly to those features which appeal to the eye, and to a lesser extent, to the taste. In practice, grading for quality concerns appearance, as there is a general agreement as to what makes an apple attractive. On other points, buyers' opinions differ considerably. To be specific, good condition implies good maturity, and freedom from water core, mouldy core, severe hollow core, internal injuries from insects (such as codling moth), bruises or unhealed surface cuts or scratches, or anything else liable to cause deterioration. Good quality implies good shape and colour for the variety, a bright clean skin indicating freshness, and freedom from disfiguring markings such as healed scratches, insect injuries, scab spots, bitter pit spots, excessive russetting, &c.

Two things are to be specially avoided in picking, namely, picking too soon and picking too late. The former results in complaints of immaturity and poor colour overseas, the greens being too green instead of yellow-green, and the reds deficient in amount and drab instead of bright and fresh. Further, susceptible varieties are almost certain to develop bitter pit, unless too immature even for pitting.

Picking too late results in complaints overseas of over-ripeness, break-down and rots. Over-ripeness, though resulting in a loss of flavour and

the development of mealiness in the flesh, is important mainly because of its relation to waste. Ripe fruit is soft and bruises readily under the prevailing handling conditions. Fungal rots rapidly follow. Further, ripe apples are subject to eye-spot rots, and fruit that is too nearly ripe when picked is very likely to be over-ripe on the markets if the temperatures in the ships' holds are on the high side, or if the sea voyage is protracted, or if the market distribution is slow. Apples of the softer varieties, particularly Jonathan and Cox's Orange Pippin, are very subject to late or maturity water core as they approach ripeness. If an affected apple is cut in half transversely, the water core will be seen as radiating translucent spots or streaks in the flesh (Plate 1, Fig. 1).^{*} If the fruit is cut in half longitudinally, the water core appears as bands in the flesh increasing in width towards the calyx end. This type of water core is not typically found in the core tissues, but sometimes a transitional form between the true water core formed in immature apples and the radial form of maturing fruit occurs. This maturity form of water core does not show external evidence of its presence and is usually overlooked. The eating quality is not appreciably affected in fresh fruit, and if stored not too long and in efficient cool stores and distributed rapidly after removal, affected fruit keeps sufficiently well. With long storage or in temperatures not sufficiently low, affected fruits develop that brown collapse of the tissues called "breakdown" (Plate 1, Fig. 2) which is one of the principal causes of the reputation for not keeping earned by these varieties. Numerous instances of water core breakdown were seen overseas in 1931 which attracted much adverse criticism especially in Jonathans. It was not uncommon for fruit to land in apparently good to excellent condition and then rapidly to collapse with breakdown. With few exceptions, water core could be detected in the collapsed fruit, which is proof that it was in an unsound condition when shipped. There is no doubt that the shipping of fruit with water core in 1931 was one of the principal causes of the complaints of non-keeping in Australian apples that season.

The best practical guide to picking is the ground colour of the fruit. Whatever shade of green an apple has when fully immature, the green is replaced by yellow or cream as it ripens, so that when it is tree ripe the green has entirely disappeared. The proportion of green to yellow provides quite an effective guide to maturity when used intelligently.

Varieties with a high susceptibility to bitter pit but not to water core and hence not to breakdown, such as Cleopatras, should not be picked until there is distinct evidence of yellow in the green, that is, until they are green-yellow.

Jonathan, Cox's Orange Pippin, Gravenstein and other quick maturing varieties subject to both bitter pit and water core breakdown should be picked mainly on the basis of avoiding water core, as breakdown is a more serious defect than bitter pit. As picking time approaches, a few of the larger and more exposed fruits should be cut and examined daily. These are the first to develop water core. Picking of the main crop should be completed before or as soon as the first evidence of water core is found. With heavy crops of these varieties, it will generally be found possible to leave the fruit until the ground colour is green-yellow thus avoiding severe pitting, poor colouring, and breakdown. In light crops, water core appears earlier, and the best picking stage is usually when the first faint signs of yellow appear in the green. Such fruit is certain to develop some bitter pit and to be poorly coloured and immature on the overseas markets. Fruit from light crops of these varieties cannot be exported without developing pit on

^{*} Facing page 60.

breakdown or both. Apples of these varieties over 2½-inch diameter are dangerous from half crops, whilst those from still smaller crops should never be exported. Varieties like Granny Smith and French Crab, which are preferred green by the trade and which have a relatively low susceptibility to bitter pit, should be picked after the first change from the full green of very immature fruit can be detected.

Varieties of good keeping reputation should be picked after the first distinct evidence of yellow is visible in the green or after the ground colour is green-yellow, according to whether their susceptibility to bitter pit is low or high.

Varieties subject to true or common water core (Plate 1, Fig. 3) such as Stone Pippin, Rome Beauty, Rokewood, Democrat, Granny Smith, and Dunn's, should be picked somewhat later than usual when the trouble is plentiful, as it tends to disappear while the fruit is on the tree. Even when affected, these varieties keep fairly well when exported. However, such fruit is not sound and good, and if delays in selling occur in the markets, it may develop breakdown. This occurred severely in the varieties Rome Beauty, Rokewood, and Democrat in 1931.

4. Grading for Export Conditions.

Good grading is essential for the development of a good reputation in marketing. It should not be confused with mere sizing, for it cannot be done mechanically.

The fruit should be divided into two or three export grades, into local market fruit, and into culls. The culls should include bruised and freshly injured fruits and those with rots, very small and badly mis-shapen fruits, and fruit badly marked, scabbed, or with codling moth, &c.

The local market fruit should include fruit with water core (the Jonathan type always, and the ordinary type when bad), fruit which is very immature or too mature for export, and oversized fruit. By oversized is meant generally 3-inch diameter or more in dessert varieties and over 3½ inch in culinary varieties. In the quick maturing varieties like Jonathan and Cox's Orange Pippin, 2½-inch fruit should not be exported unless quite firm and positively free from water core. Two to 2½-inch fruits of these varieties are preferred overseas and carry much better.

The "plain" export grade should include fruit which is somewhat immature or even slightly overmature; fruit of hard varieties like Rokewood, Democrat, Rome Beauty, &c., when affected with ordinary water core but not severely; and "bull" apples of varieties like London Pippin and Cleopatra owing to their liability to "hollow core." (Should these varieties be from light crops the general presence of "hollow core" would justify the main crop being graded "plain" and the "bulls" discarded as they are liable to develop "mouldy core"). The export regulations require that 2-inch fruit, except of naturally small varieties, shall be placed in this grade. Oversized fruit if exported should be graded "plain" as it is apt to carry badly and be defective in condition when marketed. The regulations specify the maximum allowable surface markings.

The regulations require that fruit in the "standard" grade shall be sound. This means that the fruit shall be sufficiently mature to avoid pitting in susceptible varieties, but not soft or over-ripe, and that it shall be free from water core (both forms), mouldy core, severe hollow core, rots, bruises, unhealed injuries, and internal insect injury. Though not laid down by regulation, growers are advised to separate this fruit into well coloured and poorly coloured, and to pack these separately. The regulations specify the maximum amount of allowable blemish.

If "special" grade is used, it should be made up of well-coloured clean fruit from the standard grade. In this case, the balance of the fruit remaining in the standard grade should be mixed and classed as standard (i.e., not separated into two classes based on colour as recommended in the paragraph immediately above). If this were done, the resultant proportionate increase of the content of blemished fruit in the standard grade would be offset somewhat by the better average colour. Such a pack, however, is a mixed one.

It is suggested, therefore, that no "special" grade be used and that only "standard" be packed, but that there be two sub-grades within the "standard"—a better and a poorer coloured one. In the usual season, one or other will predominate.

If the quantity of poor coloured fruit is small, it should be placed in the "plain" grade. It should be remembered that the object is not more cases of "standard" fruit, but more standardized fruit.

5. Sizing.

Sizing is very important as it is the foundation of a good pack and a fair deal with the buyer. Possible temporary gains by incorrect sizing should not be sought at the price of damage to the reputation of the industry as a whole as well as of the individual. Fruit should be sized to $\frac{1}{8}$ inch sizes and care should be taken to see that the sizing plant is clean and that it does not damage fruit.

6. Packing.

Good packing ensures a good appearance, good weight, and the maximum freedom from bruising in handling. It is surprising how little we know about packing in relation to the condition of fruit overseas, and investigations are needed to determine the best type of box and how best to pack it. Pending these, the following suggestions based upon experience in other countries and observations by the writer are offered.

1. Use the type of box most common in your State. This helps for good stowage in road and rail vehicles and in ships' holds. Remember no one knows yet what is the best case to use. The hardwood case carries fruit as well as the softwood case in use in Australia.

2. Use a well-made case of correct dimensions. This aids packing and appearance and ensures good weight.

3. Use a standard pack. Keep to that determined by the first layer in each box. Do not vary the pack in a box if it is coming too high or too low. Either a different pack is needed or the correct height should be attained by packing the fruit on its shortest or longest diameter.

4. Press firmly but gently on each layer when completed. Pack firmly by pulling the fruit forward as each is placed in position. If this is not done, some layers will be several fruits short and slack packing result.

5. If a hardwood dump case is used, bring the pack just above the surface so that the lid when nailed on shows little or no bulge. If a softwood case of the Canadian type is used, take care to avoid an excessive bulge. The value of the bulge has been exaggerated and as used is a prolific source of bruising. Though not specified in the export regulations, the use of end cleats is essential in this type of box, preferably at both ends of the tops and bottoms. These cleats should be at least $\frac{3}{8}$ inch thick. If only top cleats are used, they should be at least $\frac{1}{2}$ inch thick. In packing, a bulge not exceeding the cleats in height should be sought.

The common use of bulges $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches in height protected by cleats about $\frac{1}{4}$ inch thick means not only bruising when the lid is nailed on, but more important, bruising later on. Such cases cannot be stacked in trucks, ships' slings or holds without pressure being applied to the bulge. Pressure should be taken by the cleats and ends, and not by the bulged tops and bottoms. Such cases invariably open up with bad bruises on the fruit beneath the bulge.

6. Use woodwool between the fruit and the tops and bottoms or preferably the corrugated cardboards which surround the fruit except at the ends of the boxes. These serve to reduce bruising, but they cannot be relied upon to make up for slack or overtight packing or excessive bulging.

7. Brands, Labels, &c.

Attractive labels, easily read and properly stuck on are best, especially on hardwood boxes. Stencilling, if used, should be distinct and clean. Brands and printed labels are inadvisable except for long lines. Short lines should not be exported, for wholesale buyers do not want them. A minimum consignment of any variety, say 20 or 50, should be decided on and adhered to. Imagine the work of sorting out hundreds of brands and marks in a shipload, each with several varieties, and the difficulties of buying, selling, and bookkeeping. If there is a district packing shed, use it. Remember your name or brand is only one of thousands going from Australia. Get your fruit under a brand associated with long lines of standardized fruit wrapped in printed labels. If there is no district packing shed, get your neighbours together and start one. Aim at a brand which buyers will ask for, and retailers advertise; but you must have the quantity to meet the demand. Fewer packing sheds mean longer lines of fruit, more standardization, lower costs for handling and marketing overseas, and a better reputation for Australian fruit.

8. Conclusion.

The advice given above, if followed by those who have neglected the points raised, will help to improve the reputation of Australian apples in the coming season. Especially are growers warned against exporting the earlier and softer varieties, such as Jonathan and Cox's Orange Pippin, when affected with water core, or in large sizes. This advice applies particularly where the crops of these varieties are light, for the large sizes from such crops will be soft, will bruise readily and develop rots, and will most inevitably develop water core with breakdown as a consequence. The attention of growers in the areas affected by thrips is particularly drawn to this point.

Grade fairly, size accurately, and avoid slack or overtight packs. Especially avoid unprotected bulging of the tops and bottoms.

Finally, don't hold the earlier quick-maturing varieties after packing. If they cannot go direct to the ship's side for loading, place them in cool store. Otherwise they will arrive on the overseas markets in a more or less ripe condition.

Fruit Bud Studies: 1, The Sultana.

An Analysis of the Distribution and Behaviour of the Buds of the Sultana Vine, together with an Account of the Differentiation and Development of the Fruit Buds.

By C. Barnard, M.Sc., Botanist, Division of Plant Industry.

This investigation was carried out at the Commonwealth Research Station, Merbein, Victoria, during the years 1928-29, while Mr. Barnard was an officer of that station. The part dealing with distribution was suggested by Mr. A. V. Lyon, M.Sc., Officer-in-Charge of the Station, and the part dealing with differentiation was suggested by Dr. B. T. Dickson as a contribution to a series of studies on the differentiation of fruit buds forming part of the programme of the Division of Plant Industry, C.S.I.R. The facts set out in this paper are published principally for the benefit of the horticultural instructor and grower-experimentalist as offering a sound basis for experiments dealing with yield capacity in the vine.—Ed.

Summary.

1. The yield capacity of the sultana is limited, in many seasons, by the small number of fruit buds present.
2. Studies in respect to the distribution and development of the buds have been made as the first step in an investigation of the factors involved in fruit bud formation.
3. Records taken during four successive seasons showed that only 56% to 60% of the buds, which are present on the vine at the end of winter, develop into shoots in spring, and of these from 56% to 76% are fruit-bearing shoots.
4. The proportion of buds which develop into shoots is least at the base of the cane and increases progressively towards the distal end, and a higher proportion develop on medium length canes than on long ones.
5. The proportion of fruit buds is low towards the base of the cane, increases progressively outwards, and falls off towards the distal end in all except very short canes.
6. The seasonal variation in the proportion of fruit buds present is largely dependent upon the number of fruit buds formed on the distal half of the cane.
7. In the 1928-29 season the investigation showed that basal buds were differentiated by about 12th November, while for buds of the 16th node the date was 11th December.

1. Introduction.

During the course of the last few years, investigations have been carried out with a view to determining the factors involved in the yield capacity of various fruit trees, and the sultana has received special attention in this work. While much remains to be learned, it appears from the evidence that the yield of fruit in the sultana depends on two main factors, viz., the number of fruit buds formed and the number of berries ultimately developed on each bunch. For example, five typical vines were selected and 390 buds studied in each of two successive years. In each year some 130 buds remained dormant, while of those which grew, 53 developed fruit-bearing shoots the first year and 119 the second year. The yields resulting were respectively 111 lb. and 202 lb., these yields being closely proportional to the numbers of fruit-bearing shoots and being reflected in the total yields throughout the district for the years concerned (1925-26 and 1926-27).

The work reported here deals with the origin and development of buds and their distribution on the vine, and constitutes the first step in a study of the factors involved in the yield problem.

2. Constitution of Buds.

On a young shoot, two buds develop in the axil of each leaf, but as they are enclosed in a common protective scale they appear to the eye as one bud. As growth proceeds, they separate and one gives rise to a short lateral shoot during the season. This lateral is usually only 4 to 5 inches long, and it generally falls with the leaves in autumn. The other bud in the meantime has developed two accessory buds, one on each side, and the three thus formed are enclosed in common scales so that they appear as one large bud, which is really a compound bud or "eye." The two side or accessory buds seldom develop further and the central bud constitutes the main unit. A microscopic examination of this main bud taken in November shows that it is already quite well developed, having five or six foliage leaf rudiments, with a microscopic bud rudiment in the axil of each. It is during this period that the main unit is differentiated either as a wood bud or as one which will bear fruit, although at this stage such units do not appear different to the eye.

The compound bud remains dormant over winter.

3. Bud Burst.

The first indication of renewed growth is evident in mid-August when the central bud swells. It opens about a fortnight or three weeks later and rapidly develops as a growing shoot. Records taken at Merbein show that for eight successive years (1922-1930) the average period of bud burst extended from the 1st to the 16th of September. The seasonal variation in the period was small but was closely correlated with soil temperatures during August.

A large proportion of the buds, however, fail to burst, only 56 per cent. to 60 per cent. actually developing into shoots. There is a very slight variation in the percentage of developing buds from season to season, and there are relatively less on long canes than on short canes in any one season.

The chances of the development of a bud are also governed by its position on the cane. The proportion of terminal buds which give rise to shoots is high, whilst a comparatively large number of basal buds remain dormant. An analysis of part of the data collected during the seasons 1927-28 and 1928-29 is presented in Fig. 1, Plate 2.

Charts 1 in this figure show the percentage of buds which burst at each node on long canes, e.g., of all the basal buds examined only 20 per cent. developed shoots, as compared with 70 per cent. of the buds at the 15th nodes.

With short canes the increase in the percentage of developing buds is rapid and uniform. In the case of medium length canes, the chances of bursting increase to a certain node (4th in 1927, 6th in 1928), after which there is a slackening in the rate of increase up to the 12th or 13th node followed by an increase again towards the end of the cane. A similar feature is noted in the case of longer canes, although it is not so pronounced.

At present we know little of the factors which affect the sprouting of the buds, although soil moisture, temperature, the carbohydrate reserves of the plant, and cultural treatment are all involved.

As an illustration of the effect of cultural treatment, an experiment was carried out during the 1928-29 season designed to compare the standard practice of cracking and twisting the canes along the trellis wire with the effect of tying the ends loosely to the supports. It was found that 64.3 per cent. of the buds on the twisted or "rolled" canes developed, as against 56.7 per cent. in the case of the loosely tied canes. The difference of 7.6 represents 11.8 per cent. of the mean burst of the canes treated according

to the standard practice. As the coefficient of variation in the proportion of buds developing on normally twisted canes is 35·2 per cent. and 176 canes were used in each treatment, the difference obtained is entirely significant.

The yields from the vines used in this experiment together with relevant data are as follows :—

—	Number of Vines.	Mean Yield	Difference	Standard Error of Difference	Percentage
Canes twisted ..	87	26·44 lb.	3·13 lb.	1·17	·0024
Canes tied ..	85	23·31 lb.			

The significant difference of 3·13 lb. represents a difference of 11·8 per cent. in the mean yield of the control. It will be evident that the difference of 11·8 per cent. in the percentage of developing buds is to be correlated with the difference of 11·8 per cent. in the yield, and the importance of the number of developing fruit buds in respect to yielding capacity is strikingly illustrated in these results.

4. The Proportion and Distribution of Wood and Fruit Buds.

(1) *The Proportion of Fruit Buds.*—The proportion of fruit buds present can be determined by means of a microscopic examination of the buds during winter, as it is possible to distinguish fruit buds from wood buds on account of the presence of a rudimentary inflorescence in the former. Such an examination of 500 buds during the winter of 1928 showed that 56·5 per cent. of the buds were fruit buds, whilst a count of fruitful and barren shoots in the following spring showed that 56·0 per cent. of the shoots were fruit shoots. It may thus be possible to estimate the proportion of fruit buds present during early winter and to utilize the information at pruning.

As noted above, not all the buds burst, but the fact still holds good that 56 per cent. of those that did burst in 1928 produced fruit-bearing shoots.

This is illustrated in Table I., in which the behaviour of the buds in four successive seasons is recorded.

TABLE I.
Variation in Percentage of Fruit Buds.

Year	1 Type of Cane	2 Total Buds	3. Total Shoots	4. Fruit Shoots	5. Per cent Fruit Shoots of Total Buds.	6 Per cent Fruit Shoots of Total Shoots	7 Per cent Two-bunch Shoots of Fruit Shoots.
1926-27	All sizes ..	2,443	1,393	974	39·98	69·9	..
1927-28	Short ..	659	355	227	34·5	63·9	9·7
	Medium ..	3,746	2,149	1,536	41·0	71·5	13·8
	Long ..	2,156	1,214	814	37·6	67·1	13·6
	Total ..	6,561	3,718	2,407	36·6	64·7	13·6
1928-29	Short ..	556	360	173	31·1	48·1	8·1
	Medium ..	2,539	1,606	879	34·6	54·7	14·2
	Long ..	4,157	2,444	1,418	34·1	58·0	12·6
	Total ..	7,252	4,410	2,470	34·0	56·0	12·8
1929-30	Short ..	233	134	90	38·6	67·2	8·0
	Medium ..	2,674	1,606	1,197	44·8	74·5	21·6
	Long ..	5,346	2,923	2,266	42·3	77·5	26·6
	Total ..	8,253	4,663	3,553	43·1	76·2	24·5

The coefficient of variation in the percentage of fruit buds on individual canes reached a maximum of 34 per cent. in the 1928-29 season, and the differences shown between the three seasons 1927-28, 1928-29, 1929-30 are all significant. The short canes are the least, and the long ones the most, fruitful, but as the proportion of buds which develop on medium length canes is greater than that on long canes, the former are the most suitable type. This feature is illustrated in column 5 of the table in which the number of fruit shoots as a percentage of the total buds is given. Roughly, 75-85 per cent. of the fruit shoots carry a single bunch, and the remainder two bunches. This proportion varies from season to season, and is an obvious factor in yield capacity.

(ii) *The Distribution of Fruit Buds*.—An analysis of the distribution of the fruit shoots on long canes during two seasons is graphically illustrated in Charts 2 and 3, Fig. 1, Plate 1, where the number of fruit shoots is expressed as a percentage of the original number of buds present.

The charts in Fig. 2, Plate 2, represent the number of fruit shoots on the three classes of canes as a percentage of the total number of shoots present. It may be assumed that these charts indicate the number of fruit buds as a percentage of the total number of buds.

In each case, the proportion of fruit buds is very low at the basal node, and increases rapidly to the 4th or 5th node. From this point to the end of the cane, a gradual increase or decrease is apparent. On the average for all canes, the percentage of fruit buds at the 6th and 7th nodes is the same in the three seasons 1927-28, 1928-29, and 1929-30. The differences in the percentage of fruit buds formed in the three seasons is clearly shown to be due to a difference in the fertility of the buds along the distal half of the canes. The smaller percentage of fruit buds in 1928-29 is very largely due to a decrease in fertility in the buds towards the ends of the long canes in that year. Under such conditions, the use of a greater number of medium length canes would materially increase the yield capacity of the vines.

5. The Differentiation of Fruit Buds in 1928-29.

(i) *The Structure of the Bud*.—A transverse section near the apex of the bud (Fig. 1, Plate 2) illustrates the arrangement of its component structures. The rudimentary foliage leaves develop alternately from opposite sides of the axis. Each leaf (*l*) is accompanied by two stipular scales (*sc*) which stand face to face. Longitudinal sections may be cut in two directions—one passing along the plane in which the leaves are situated and the other in the plane at right angles to this. In the latter case no leaves are evident in a median section (Fig. 2, Plate 3). In the former case the foliage leaf rudiments are revealed, but only the cut edges of the scales are shown towards the top of the section (Fig. 3, Plate 3).

The growth and development of the foliage leaf can be followed to a certain extent in a single bud. In Fig. 3, Plate 3, the alternate arrangement of the leaves on the axis is illustrated and various stages in growth of the leaf depicted. The youngest leaf (at 1) is narrow and pointed upwards.

(ii) *Initiation and Development of Inflorescence Anlagen*.—Perolt* states that Muller-Thurgau (1892) and Behrens (1897) investigated the differentiation of the inflorescence primordia in the grape. It was noted that the initiation commenced in the oldest (basal) buds first and proceeded upwards to the distal buds of the shoot. In Europe, the differentiation commenced in the basal eyes for the first bunch about the middle of June and for the second bunch at the beginning of July. About the beginning of August, all the

* Perolt, A. I. A Treatise on Viticulture, 1927. MacMillan and Co.

rudimentary inflorescences that can develop into bunches the next year have been formed. Development of the rudimentary inflorescences proceeds until October when the eye enters upon its winter rest. In the Western Province of the Cape, Perolt remarks, the corresponding dates are about the middle of November, beginning of December, beginning of January, and March. The growth of the grape in the Mildura district according to our observation is slightly in advance, by about two weeks, of that at the Cape.

The first indication of the formation of an inflorescence primordium is the division of the apex into two more or less equal growing points (Fig. 4, Plate 3). The division indicated at "p" in this photomicrograph is the inflorescence initial whilst the apical tissue subtended by the leaf "l" becomes the new organic apex of the bud. The usual interpretation of this division is that the inflorescence primordium is formed from the original apex of the bud and is thus terminal in position whilst the new organic apex arises from a meristem formed in the axil of the youngest leaf, the growth being sympodial. It has, however, been pointed out by Goebel* that the tendrils of the vine which are phyletically derived from inflorescences "are not formed as evident continuations of the internodes below them and then only gradually pushed to the side by the stronger growth of the uppermost axillary shoot, but that they either from the first have the leaf opposed position or that they proceed from the apex of the axis itself through its unequal division." Our observations support this view.

The configuration of the inflorescence primordium becomes characteristic almost immediately after its initiation, and is easily distinguished from the leaf primordium (at "p," Fig. 5, Plate 3). Subsequent development results in a large structure, upon which numerous growing points develop, and which in late summer projects considerably beyond the organic apex of the bud.

The first inflorescence primordium is usually formed opposite the 8th or 9th rudimentary leaf, and a second inflorescence, if present, opposite the 10th or 11th. Owing to the fact that the basal nodes do not elongate when the bud bursts, the inflorescence usually appears to be situated at the 5th or 6th node on the shoot.

(ii) *The Time of Differentiation of the Inflorescence Primordia in 1928-29.*—Differentiation of the primordia occurred in the basal buds first and progressed outwards along the shoot, the basal buds showing the first indication of inflorescence initiation about the 12th of November and the 16th bud about the 11th December.

Although insufficient material was examined to determine definitely the time of differentiation in the basal buds, owing to the high percentage of wood buds in this region of the shoot, it is very probable that differentiation had occurred in the first and perhaps the second bud on average shoots by 12th November, but no signs of differentiation were found prior to this date. Results show that the differentiation of the inflorescence primordia occurred in average shoots as follows:—

In the 1st bud on 12th November (approx.).
 6th bud on 20th November.
 8th bud on 28th November.
 10th bud on 5th December.
 16th bud on 11th December.

The time therefore during which the buds, situated on that part of the shoot retained by the pruner, may differentiate as fruit buds is limited to a

* Goebel. *Organography of Plants*. Part II., p. 436. 1905. Eng. Trans. Oxford.

period of approximately four weeks. It follows that this period is a critical one in so far as the proportion of fruit buds formed at this time governs the yield capacity of the vine in the following season.

6. Acknowledgments.

It is desired to express appreciation to Dr. B. T. Dickson, Chief of the Division of Plant Industry, C.S.I.R., at whose request the differentiation studies were commenced, and who made valuable comments and suggestions in the preparation of the text. For initiating the studies relating to the analysis of the distribution and behaviour of the buds, and for assistance during the investigations, the author desires to thank Mr. A. V. Lyon, M.Agr.Sc., Officer-in-Charge, Commonwealth Research Station, Merbein.

St. John's Wort in Australia.

By J. Calvert, M.Sc., Division of Plant Industry.

The article that follows deals mainly with the botanical aspects of the St. John's wort problem. As indicated by Mr. Calvert, the Division of Economic Entomology is making an exhaustive study of the possibilities of controlling the weed by insects. (See this Journal 1 : 78, 1927. 3 : 127, 189, 231, 1930.)

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|---|------------------------|
| 1. Introduction | 4. The Plant. |
| 2. History of Infestation in Australia. | 5. Biological Control. |
| 3. Distribution. | 6. Chemical Control. |

1. Introduction.

The St. John's wort of Australia belongs to the genus *Hypericum*, of the richly developed family Guttiferae, which shows its most common distribution within the tropical belt. *Hypericum* is the only genus of the family which occurs extensively outside the tropics, whilst within the tropics it is confined to high mountainous areas. It does not penetrate to the Arctic regions, nor to the high Alps. Within the tropics, the other representatives of the family are almost all inhabitants of high rainfall areas. *Hypericum* is more widely distributed than any other genus of the family, and possesses over two hundred species. The tribe Euhypericum occurs over the whole of the northern hemisphere; *Androsaemum* occurs in the Mediterranean district and North America; *Norysea* ranges from Africa, India, to Japan; and *Brathys*, from South America to North America and Japan. At present five species are recorded in Australia, chiefly confined to the States of Victoria and New South Wales, viz.:—

H. perforatum L., which is regarded as the St. John's wort pest, occurs also in Europe, Northern and Western Asia, China, India, North Africa, and North America.

H. androsaemum L. (Tutsan), grows in abundance at Apollo Bay, in Victoria. It ranges from Europe to Western Asia, South Africa, and New Zealand.

H. calycinum (large flowered St. John's wort), in Victoria.

H. gramineum Forst., in New South Wales, Victoria, and Queensland, and also in Tasmania, New Zealand, and New Caledonia.

H. japonicum Thunb., in Victoria and Queensland, and also in New Zealand, Malay Archipelago, India, China, and Japan.

A great number of species have become widely distributed through a large part of the Mediterranean area, and a large part of North and South America, but it is apparently only in Australia that the plant has become a serious pest. Of recent years, however, it has increased rather alarmingly in one or two localities in Canada.

It is suggested by Engler and Prantl, and by Rendle, that a factor in the wide distribution of this genus may be the carriage on the feet of birds of the small seeds, which are produced in large numbers. Winds also may have been a factor.

2. History of Infestation in Australia.

(i) *Bright, Myrtleford, and Gippsland*.—The original infestation is generally considered to have been caused by a German woman of Bright, who introduced it from her own country during the gold-mining boom in the Ovens Valley. Apparently it escaped from cultivation, and took complete possession of the old racecourse. This, in its turn, gave rise to the local name of "racecourse weed." So thick did the weed become on the racecourse that when the racing season opened, a track had to be formed round the course by mowing. It was not long before the hillslopes from Harrierville to Myrtleford were strongly infested. Gold, at this time, was discovered at Wonnangatta and Grant, in Gippsland, on the other side of the Dividing Range, and the miners of Bright, with their pack-horses carrying chaff, &c., transported the weed seeds across the mountains, where it is now well established. It occurs up the mountain side as far as the snow line, but is reported as not always producing seed at such an altitude, and under such conditions.

(ii) *Tumbarumba, New South Wales*.—The infestation in this area was initiated at, or near, the garden of the old McMicking homestead, at Mannus. There are two theories as to how it arrived there, viz.:—
(a) from the Bright district, by a hawker, in the chaff for his horse; or
(b) by importation by a local family from England or Germany, either intentionally as a decorative plant, or accidentally with decorative plants, for the garden surrounding the family burying ground.

It was first observed about 1899, but no alarm was felt, for the rate of spread was slow, and the station, at this time, was devoted chiefly to sheep. The New South Wales Government purchased the McMicking estate as a soldiers' settlement area, about August, 1926, and with the commencement of cultivation and dairying, the weed spread rapidly.

3. Distribution.

The weed ranges in Victoria, southwards up the valleys from Bright, into the Victorian Alps, and across the mountains to the headwaters of the Gippsland rivers; northwards, it passes Beechworth and Wangaratta, and has crossed the Murray River near Albury into New South Wales. In the latter State, some 3,500 acres in the Mannus district of Tumbarumba, are heavily infested, whilst about another 3,000 acres further

afield are less heavily infested. The infestation is also dense in the shires of Cudgegong, Crookwell, Gadara, Canabolas, Rylstone, Tumbarrumba, and Blaxland, and scattered and light in the shires of Holbrook, Muswellbrook, Culcairn, Lyndhurst, Adjungbilly, and Dalgety. A transect was made at Tumbarrumba, and Fig. 2, Plate 4, shows the result. It can be seen that a pure stand of St. John's wort occurs at the base of the transect, and merges into a pure stand of bracken on ascending the hill. Patches of the wort occur in the bracken. The absence of areas of bracken in the St. John's wort, and the presence of dead bracken plants would indicate fairly definitely that the wort is invading the bracken area. In South Australia, the areas affected are Coromandel Valley to Bridgewater (1,300-1,500 acres), Port Lincoln (50-60 acres), and Clare, Yankalilla, and Birdwood. In Tasmania it occurs at Scottsdale, and possibly at other places.

Some idea of the rate of increase of the weed can be obtained from the figures in the following table, but it should be borne in mind that the plant is a perennial, and retains its ground from year to year, except where determined measures have been taken to eradicate it:—

AREAS OF INFESTATION IN VICTORIA AT DIFFERENT PERIODS.

Year	Acres		Total.
	Crown Land	Private Property	
1880	..	1	1
1902	2,910	5,639	8,549
1905	4,000	6,210	10,210
1916	156,000	28,000	184,000
1931	..	..	244,519

(Figures up to 1916 taken from an abstract by W. B. Alexander, of the former Advisory Council of Science and Industry in 1917.)

4. The Plant.

(i) *Short Description*.—St. John's wort is a branched perennial with a creeping rootstock, which is very fragile, and has deep penetrating roots. It grows stiffly upright, reaching 2 feet or more in height; the leaves are about half an inch long, elliptical or linear-oblong, opposite and sessile, and have pellucid dots. Their arrangement causes the stem to appear to "perforate" them, hence the specific name. The flowers are bright yellow in colour, and about 1 inch in diameter, and are clustered in cymes. The petals are dotted with black, and are twice the length of the lanceolate sepals. The number of long yellow stamens is a feature of the flower. The numerous seeds are contained in capsules. During the winter the seed capsules are borne on the dead brown stalks, while a fresh prostrate matted growth is developed, to the exclusion of other vegetation.

(ii) *Botanical Classification*.—When dealing with a plant which is suspected of having toxic properties, or which is a noxious weed, possibly subject to biological control, it is important to know the correct botanical classification. In the year 1928, Sir Arthur Hill, Director of the Royal Botanic Gardens, Kew, pointed out to the Council that he was very interested in the work on *Hypericum perforatum* L., and stated that he

was not at all sure as to the form of *H. perforatum* which had been introduced into Australia. He, therefore, asked for specimens to be sent to him to enable a correct identification to be made. As a result, specimens were sent from New South Wales, Victoria, and South Australia. Subsequently, he drew attention to the article in the Council's Journal by Seddon and Belschner (1929), which dealt with the poisoning effects of St. John's wort, and this time asked for specific specimens of the weed with which these experiments were made. It is now accepted that the plants tested belong to the continental form known as *Hypericum perforatum* L. var. *angustifolium* D.C. Other material forwarded to Kew more recently has also been so identified.

(iii) *Method of Spread*.—It has been mentioned previously that the plant produces a prolific number of small seeds, which may adhere to the feet of birds. The seeds are contained in a sticky capsule, which may also adhere to the coat of horses, cattle, sheep, rabbits, &c. Seeds are also said to be capable of passing through the alimentary canal without losing their germinating power. Fodder was the medium for transport across the Victorian Alps. Wind, floods, and ants also play a part in the dispersal. The plant itself is a perennial, with creeping rootstocks, which grow out from the parent plant, and at intervals a shoot appears, which forms a new plant. It is this particular method of propagation and growth that gives rise to consolidation of the pest in areas infested.

(iv) *Effect on Stock*.—Photo-sensitization of the unpigmented surfaces of the body of stock, &c., which eat St. John's wort has been recorded in several parts of Australia, and by different observers. Seddon and White, 1927-28, during experiments on the toxic principle of this weed, found that sensitization is induced by feeding it to sheep, or by the subcutaneous injection of the juices. Sheep suffering from an acute phase of photo-sensitization and dermatitis exhibit hyperpyrexia. In the district of Tumbarumba, 240 merinos grazing on St. John's wort country suffered from hyper-sensitivity and dermatitis, and after two months 40 were dead. On being put on clean country, the remainder recovered in about six months. Dodds (1920) states that, as well as the skin affection, an influence is exerted on the central nervous system, usually causing great mental depression, but at times the very reverse effect takes place, i.e., excitement, almost approaching mania. Henry (1922) also reports photo-sensitization, &c., from some feeding experiments on cattle and sheep, and Seddon and Belschner (1929) found by feeding the young immature plant to sheep that ingestion caused the usual type of dermatitis from photo-sensitization.

5. Biological Control.

(i) *By Other Plants*.—(a) *Pinus radiata (insignis)*.—The original infestation on the old racecourse at Bright is now clean land, under a good stand of *Pinus radiata (insignis)* planted by the Forestry Commission in 1916. At one or two places in the plantation, a tree has been felled or a firebreak or clearing has been made, which enables the sunlight to penetrate directly to the ground, and in these places the weed is to be found growing, although it is somewhat etiolated and, as far as can be ascertained, develops few seeds as compared with the normal plant. The length of time a seed lying in the soil retains its viability is not known. In the country around Tumbarumba, New South Wales,

pine plantations are also being grown. However, control measures are desired which will keep the pest from spreading along the fertile pastures of the Murray River valley.

(b) *Subterranean Clover*.—Due to its dense covering growth, this plant has been suggested for use in choking out the weed. Individual plants of *Trifolium subterranean* will possibly cover the whole of a circle 6 feet in diameter, whilst a good stand of plants will cover the whole land with a dense mass of growth from 12 inches to 20 inches in height.

(ii) *By insects*.—The possibility of control by insect enemies of St. John's wort is being exhaustively studied by officers of the Division of Economic Entomology.

6. Chemical Control.

(i) *Common Salt*.—French (1904-5) conducted experiments with a variety of chemicals, and indicated that the treatment with salt was the most satisfactory of those used. Pammel, King *et al*, of Iowa, in their comprehensive bulletin, recommend the use of salt.

Control by salting is practised by the Victorian Department of Agriculture, at Myrtleford, and some success is achieved, though it is an expensive method. The first object of the authorities in this district was to clear the stock routes, and at all costs, to prevent further widespread distribution of the weed. A zone or strip, 12 yards wide, was mowed before the plant came into flower. The following year, a further 12-yard zone was mowed, whilst salt was spread on the previous year's zone at the rate of about six tons to the acre. Thus each year, a new 12-yard zone is mowed, and the area of the previous year's mowing is salted. In this way, the weed is being gradually pushed up the hill slopes away from the stock routes. Salt costs £1 17s. per ton off rail, and cartage, varying from 5s. to £3 per ton, according to distance and elevation, makes the total cost of control between £20 and £30 per acre, inclusive of labour.

(ii) *Chlorates*.—As a result of recent work, chlorates are rapidly becoming recognized as of the greatest value in the destruction of weeds. The earliest record of their use as a herbicide, according to the literature available to the author, dates from 1901, when potassium chlorate was applied to prickly pear in Queensland, but the results obtained then seem to have been unsatisfactory. It is only during the last decade, however, that the use of chlorates has been revived, and now they are being tested quite extensively. The new experiments seem to have been begun in France by Loyer (1923), and in the course of reporting the results of his experiments he mentions the fact that Rabaté recommends the application of 250 kilograms of sodium chlorate per hectare, in a 2 per cent. solution, for the destruction of all vegetation in garden paths, &c. Loyer used a 1 per cent. solution of ammonium chlorate for the destruction of annual weeds in grain crops, adding that an application of 25 kilograms per hectare will not injure the grain.

As a result of Danish experiments in 1925, a 5 per cent. solution of sodium chlorate, applied at the rate of 6,000 to 8,000 litres per hectare, was recommended for eradicating all weeds on garden paths, &c., and a 1.5 to 2 per cent. solution, at the rate of 1,000 litres per hectare for annual weeds in grain crops. Korsmo (1925, 1927) reports an application of a 5 per cent. solution of sodium chlorate, at the rate of 1 litre

per square metre, killing eleven species of perennial weeds, including Canada thistle. Eight other perennials, including quack grass, *Agropyron repens* (L.) Beauv., were not killed by a single application. Feilitzen (1925) also recommends the 5 per cent. solution, at a litre per square metre, for all vegetation on tennis courts, &c. Aslander (1925) used dilute solutions of sodium and potassium chlorate for the eradication of annual weeds in grain crops, and they were found to injure the grain almost as much as the weeds.

Latshaw, W. L., and Zahnley, J. W. (1927), considered the efforts to control the perennial field bindweed (*Convolvulus arvensis* L.) with sodium chlorate (12.5 per cent.) spray applied after the full bloom period gave most promising results. The same authors, in 1928, suggested the use of magnesium and calcium chlorate in place of sodium chlorate, since these do not present the same fire hazard as that encountered with the latter.

Hansen, A. (1928), reported satisfactory results when heavy applications of sodium chlorate were sprinkled in water solution over mowed areas of quack grass. In 1929, he reported sodium chlorate as effective on perennial weeds in Indiana, when applied in three successive applications of 1½ lb. each per square rod.

The attention of Deem (1930), in New Zealand, was directed to the use of chlorate by the work done in the United States in the control of bindweeds. Reports received about that time from the Victorian Railways Department, which was testing calcium chlorate, were so favourable that it was decided to give both chlorates a trial. Deem (1930), in his experiments with these chemicals, found that either of them could be used in the control of St. John's wort, ragwort, pennyroyal, ox-eye daisy, and other soft weeds, a 100 per cent. kill being reported. In the control of ragwort, when used at strengths not greater than 5 per cent., there is only slight burning of the pastures, and they rapidly recover, although the ragwort is effectively controlled. Stronger solutions (20 per cent.) produce more burning, and the pastures take longer to recover. Chlorates are used by the South Australian Department of Agriculture, at the rate of 100 lb. of sodium chlorate in water to make 100 gallons of solution.

Some accidents have been reported in the use of chlorates, due to their combustible nature on drying, but precautions are now being taken against these by the admixture of the deliquescent calcium chloride, which is sufficiently attractive to moisture to reduce the danger of fire to a very marked extent.

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Timber Utilization Studies.

An Investigation of Certain Australian Hardwoods for use in Rollers, Bobbins, &c.

By H. E. Dadswell, M.Sc.

A matter of considerable importance to the Australian timber industry is the utilization of local timbers to replace imported species which are used for definite purposes. To enable such a replacement to be made satisfactorily, however, it is necessary to obtain timbers closely related both in structure and properties to the imported species. This, in its turn, cannot be done unless extensive information regarding the structure of the local material is available. To obtain that information is one of the objects of the Wood Structure Section of the Division of Forest Products. The Section has already completed some work with a view to determining suitable Australian timbers for use in rollers, bobbins, &c.

At the present time the timber used especially for this purpose is alder (*Alnus* spp.), a timber that has to be imported either from North America or Europe. The species common in the United States and Canada is red alder (*Alnus rubria*) while that common in Europe is black alder (*Alnus glutinosa*). The timber of this genus is generally used in turnery, the manufacture of bobbins, common toys, foundry patterns, wooden ware, dug out canoes, &c. The wood is recorded as being compact, close grained, and brittle, yet easily worked. It seasons readily, turns and curves well.

The wood from this species is classed as diffuse porous, the pores being barely visible without a lens. The annual rings are plainly visible; some large rays are present similar to those in oak, but these are not numerous. The small rays are quite numerous and inconspicuous on the longitudinal faces. Microscopic examination shows that the pores are very small, are septate and numerous (see Plate 5, Fig. 1). The rays are quite numerous and are mostly uniseriate (one cell wide). In the heartwood, these rays contain a definite coloured extraneous material. The pores and wood fibres, when seen on a transverse section, are thin walled throughout the greater part of the growth ring, with the exception of several layers of cells at the end of the season's growth. Wood parenchyma is present, and is diffuse and scattered. It contains a certain amount of extraneous material.

On the basis of this knowledge, several Australian timbers were examined and their structure and properties compared with those of this species. The timbers in which a definite similarity was noticeable were myrtle (*Nothofagus cunninghamii*) and sassafras (*Atherospermum moschatum*), as well as the introduced willow (*Salix* spp.).

Microscopically, the myrtle and sassafras appear very similar in structure to the alder (see Plate 5, Figs. 2 and 3). The cell walls, however, are thicker, and this is the reason for the greater density of these species. The pores are septate, of approximately the same size, and as numerous. The rays are nearly as numerous, but slightly larger,

being two cells wide (biseriate), in comparison to the uniseriate rays of the alder. Willow is also quite similar to the alder in structure, but is possibly somewhat light and too soft to replace this species in use.

Myrtle has physical properties decidedly similar to those of alder. It works well, does not "fur," and turns exceedingly well. Being somewhat denser, it is used in flooring, decking, and wooden tram rails. It is also used in tool handles, shoe lasts, shoe heels, turnery, cooperage, &c. It seasons more slowly than alder.

Sassafras is also somewhat denser than alder, and is used in turnery, carving, pattern making, and the manufacture of small domestic articles.

On the basis of both use properties and structure, it seems that these species could be very well utilized to replace alder in rollers. At best, they are well worth a trial in this respect.

PLATE 1.

(The Export of Australian Apples. See page 40.)

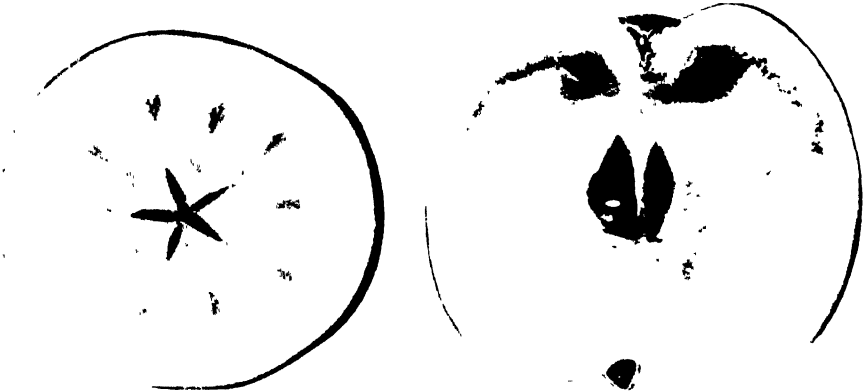


FIG. 1.—Maturity or radial water core in Jonathan at time of picking.
Note that the core is not affected.

Photograph by R. C. Palmer, British Columbia.

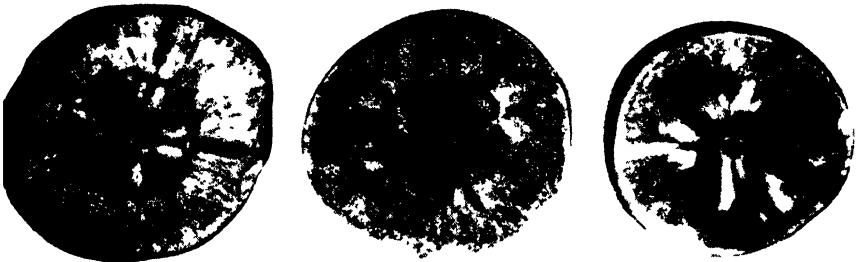


FIG. 2.—Water core breakdown in Australian Jonathans. The darker radiating spots indicate the water core.

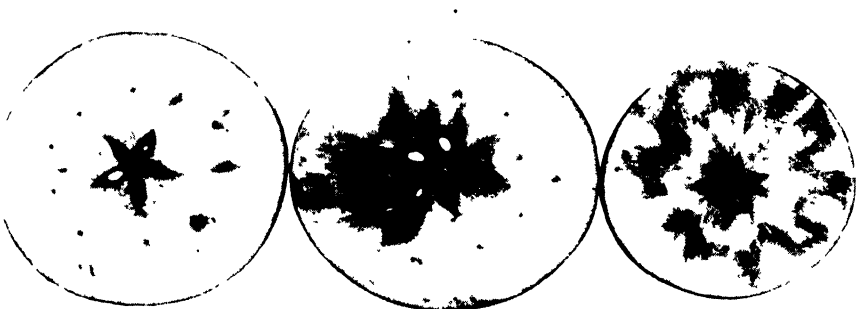


FIG. 3.—Common or immaturity water core in Granny Smith apples when picked. Recovery had commenced in the apple on the right, and was nearly complete in that on the left.

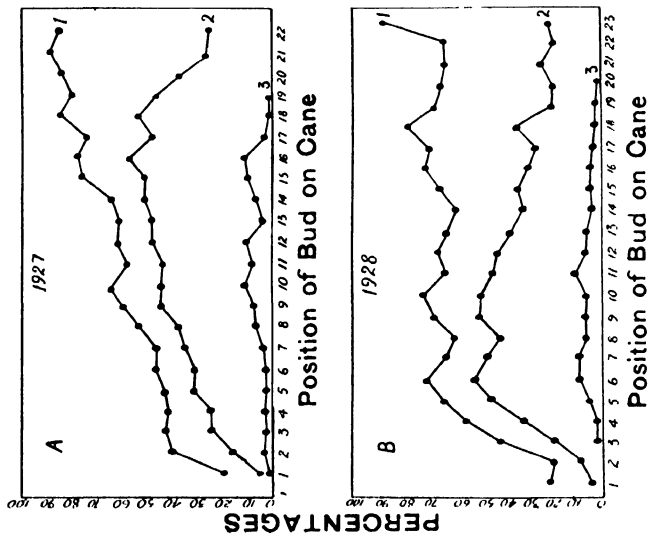


FIG. 1.

FIG. 1.—Charts showing the relation between the behaviour of the bud and its position on long canes. Chart 1 shows the percentage of buds which burst; Chart 2 the number of fruit shoots produced, as a percentage of the total number of buds; and Chart 3 the number of shoots bearing two bunches as a percentage of the total number of buds.

FIG. 2.—Charts showing the proportion of fruit buds at each node on the canes in three seasons. A. represents short canes with ten buds or less; B. medium length canes with more than ten buds but less than sixteen; and C. long canes sixteen buds or more. In D the charts are composite, including canes of all sizes.

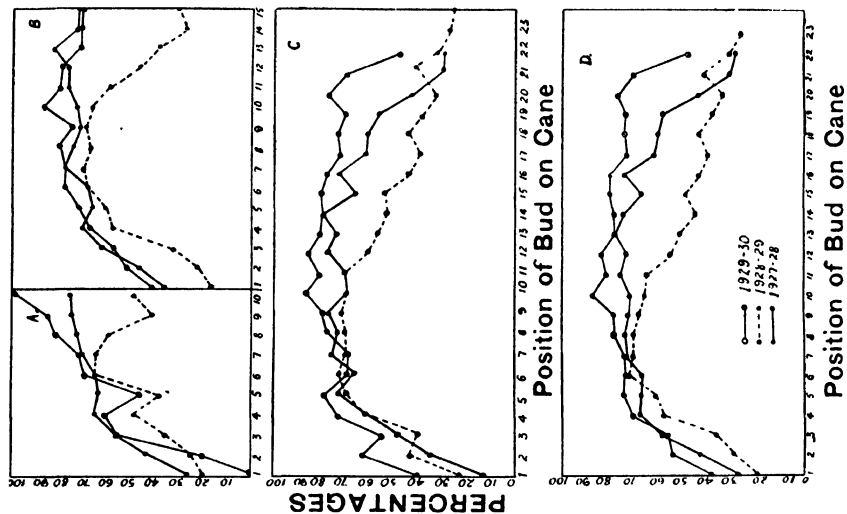
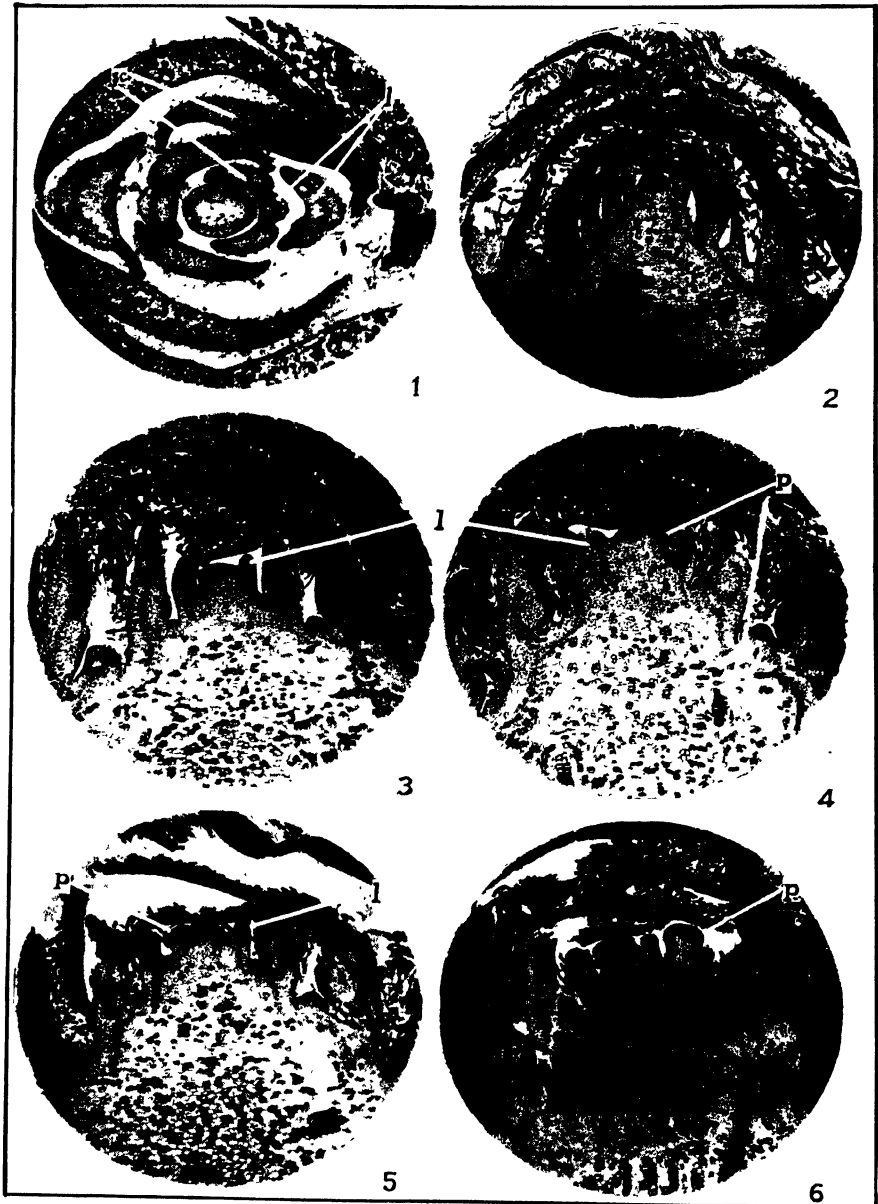


FIG. 2.

PLATE 3.

(Fruit Bud Studies: 1, The Sultana. See page 47.)



PHOTOMICROGRAPHS OF SECTIONS OF THE CENTRE BUD OF THE EYE $\times 33$.

FIG. 1.—Transverse section of bud near apex. Foliage leaves at "l" and stipular scales at "sc." FIG. 2.—A median longitudinal section of a bud, cut along the plane at right angles to that in which the leaves are located. FIG. 3.—A median longitudinal section of the 15th bud, 28th November. This section is cut along the plane in which the foliage leaves are situated. The youngest leaf is shown at "l." FIG. 4.—A section of the seventh bud, 20th November, showing an unequal division of the apex. Inflorescence initial at "p." FIG. 5.—The sixteenth bud, 11th December, showing the young inflorescence primordium at "p" opposite the leaf "l." FIG. 6.—Seventh bud, 11th December, primordium at "p."

PLATE 4.

(St. John's Wort in Australia. See page 52.)



FIG. 1.—Showing the density of growth and height of St. John's Wort in a badly infested area.

Photograph by G. A. Currie.

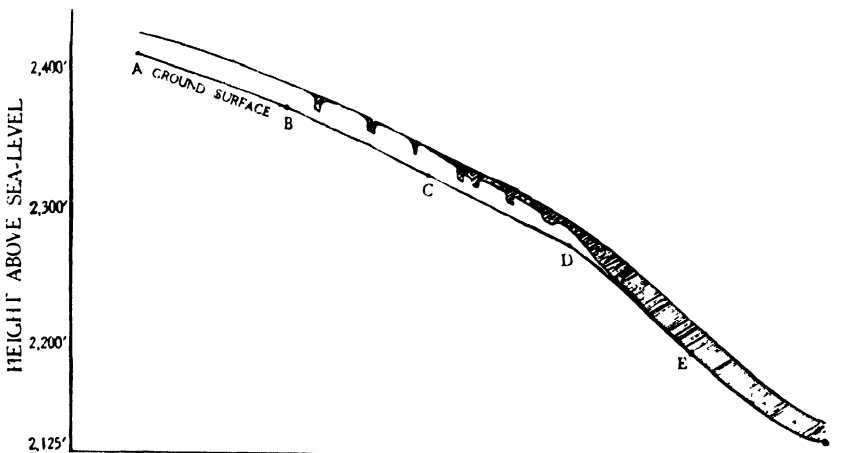


FIG. 2.—Illustration of the density of St. John's wort (shaded) and bracken (unshaded) in relation to elevation on a transect in the Tumbarumba district, New South Wales. $AB = BC = CD = DE = 50$ metres.

PLATE 5.

(Timber Utilization Studies: An Investigation of Certain Australian Hardwoods for Use in Rollers, Bobbins, &c. See page 59.)

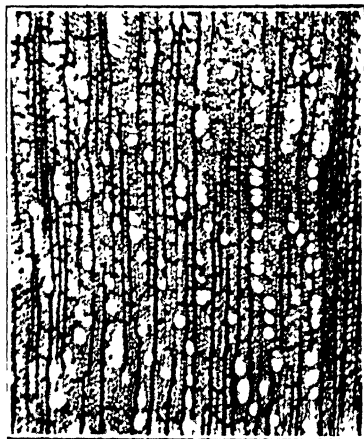


FIG. 1.—Cross section of alder
(*Alnus* sp.) $\times 35$.

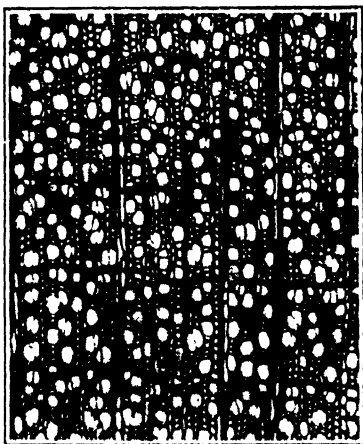


FIG. 2.—Cross section of sassafras
(*Atherospermum moschatum*) $\times 35$.

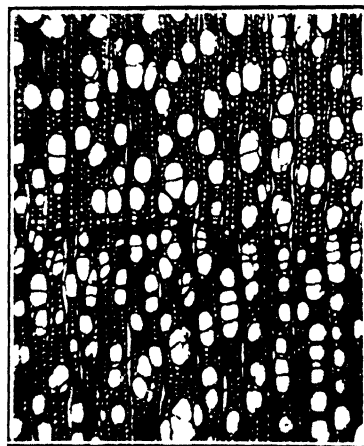
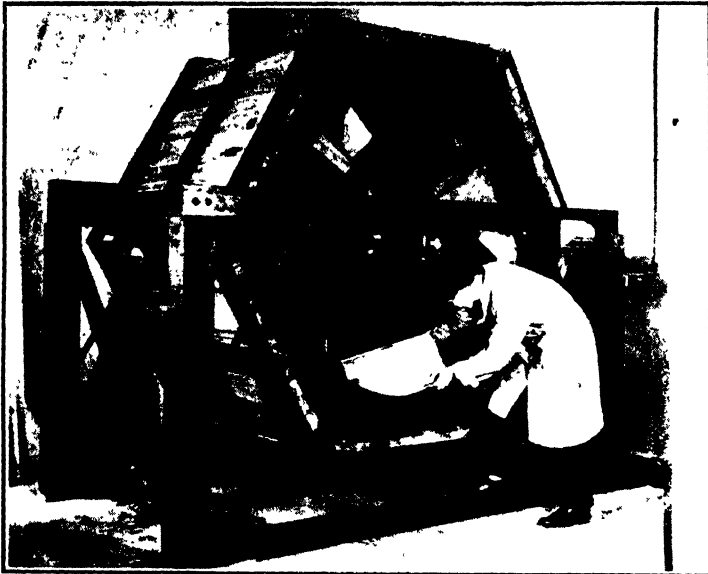


FIG. 3.—Cross section of myrtle
(*Nothofagus cunninghamii*) $\times 35$.

PLATE 6.

(The Better Design of Boxes. See page 68.)



The new Box-testing Drum of the Division of Forest Products.

NOTES.

The Council's Recently Established Section of Food Preservation and Transport.

Although the Council has long had in mind serious concentration on the problems of the preservation and transport of foodstuffs, owing chiefly to the lack of funds and suitably trained investigators, it had to postpone the formation of a suitable research organization in this field until last year. In the meantime, isolated yet valuable investigations on such problems as the prevention of drip from thawed beef, the transport and maturation of bananas, and the storage and transport of oranges were initiated. The lack of investigators experienced in this branch of applied science was met by appointing several young graduates to be trained overseas and financed by the Science and Industry Endowment Fund. The return of three trainees last year corresponded with the economic crisis, and the Council was unable, therefore, to proceed with its original plan for the creation of a separate Division for research on Food Preservation and Transport. Following tentative outside offers to provide laboratories for this type of work and a report by Dr. J. R. Vickery embodying the chief problems of preservation and transport of perishable foodstuffs in Australia and a suggested organization to meet current requirements and limitations*, in August last the Council established a small Section of Food Preservation to study problems concerning meat, fish, and tropical and non-tropical fruit. Dr. W. J. Young will continue to act as the Council's Adviser in food preservation matters, and Dr. J. R. Vickery has been appointed officer-in-charge of the Section. The staff will consist initially of an engineer to study transport problems (Mr. N. E. Holmes, B.E.E.), a plant physiologist for work on non-tropical fruits (Dr. S. A. Trout), a biochemist working on the maturation of bananas (Mr. E. W. Hicks, B.Sc.), and a biochemist studying problems of meat preservation (Mr. W. Empey, B.V.Sc.).

A survey has shown that it will be possible to carry out all the investigations likely to be required for many years to come in laboratories situated in Brisbane and Melbourne. Owing to a generous offer by the Queensland Government made through the Queensland Meat Industry Board, the Brisbane laboratory, where problems connected with meat and tropical fruits will be studied, will shortly be erected at the Meat Industry Board's works, Cannon Hill. The investigations likely to be carried out during the first few years of operation of the Brisbane laboratories will include a study of the chilling of beef with a view to its export from Queensland to Europe, and investigation of the freezing, storage and thawing of edible offal and possibly also of bacon pigs with a view to their being utilized abroad for the manufacture of hams and bacon. The transport of tropical fruits from Queensland to the Southern States also constitutes a problem to be studied in Brisbane. A provisional agreement for co-operative research work with the Victorian Department of Agriculture, which has laboratories and experimental cool chambers at its Victoria Dock Cool Stores, will provide for the problems in the storage and transport of non-tropical fruit. The initial experiments, on the ripening of pears,

* This report has been published as the Council's Pamphlet 23.

carried out under this agreement have already been commenced. Negotiations for further co-operative work are now in progress with a view to the initiation of work on a programme of research work which includes a study of the orchard and storage conditions affecting the keeping quality of the leading varieties of apples exported from the Southern States, storage experiments on passion fruit, and the gas-storage of peaches and plums.

The experiments on the storage and transport of oranges will be continued under the auspices of the Council's Citrus Preservation Committee with which the Section of Food Preservation will co-operate.

Quick Frozen Carton Meat.

In the Council's Journal for August, 1931 (Vol. 4, pp. 100-106), an article by Dr. J. R. Vickery was published giving a short account of the methods adopted in the United States of America for the quick freezing of packaged meat. The writer pointed out that several meat packing firms in that country, stimulated by the commercial success of quick frozen fillets of fish, were producing quick frozen cuts of meat on a fairly considerable scale. He indicated, however, that in connexion with the possible application of these methods to the export of quick frozen carton meat from Australia, there were certain real difficulties both of a technical and commercial nature.

The Council has recently obtained the opinions on this matter of several persons in Australia engaged in the meat export trade. Several of the more important meat companies in Australia have been closely watching for some time past developments in quick freezing, and some of them have already carried out tests on certain of the processes, while others have inspected products treated by various processes. The opinions expressed by those whom the Council have consulted indicate that there is little likelihood of the development, at any rate in the near future, of an Australian export trade in quick frozen carton meat. Some of the chief difficulties in the way of such a development as indicated by those whom the Council has consulted, may be summarized briefly as follows:—

1. *Maintenance of Proper Temperatures.*—Meat treated by quick freezing processes would leave the freezing works at a temperature of about -10°F , and would have to be stored during transport on board ship at about 0°F . The shipping companies are not at present able, for the most part, to grant facilities for cold chambers at so low a temperature, and they would probably be unable to do so without substantial increases in their freight charges. Moreover, the necessary alterations in the present methods in Australia so as to operate "quick freezing" would necessitate the expenditure of a large amount of capital in order to make existing plants efficient at the lower temperature. Such expenditure would not be justified before definite proof could be given that financial benefit would result.

2. *Commercial Difficulties.*—As quick freezing processes have so far been applied successfully only to small pieces of meat (not exceeding about 6 lbs. in weight) from the best cuts, a premium would be placed on these cuts, and it would be difficult to find a profitable method of disposing of the cheaper cuts. The treatment would be too expensive,

and the loss in carcasses too great to enable a profit to be made. The process is not likely to be commercially practicable so far as the Australian export trade is concerned, until it can be applied economically to larger pieces of meat than at present. The margin of profit in freezing works is small, and the meat companies are not likely to increase their costs in the installation and operation of new plants until they are assured of better returns than they receive at present.

3. *Retail Difficulties.*—In addition, there would be serious difficulties with respect to retail arrangements in Great Britain. In the first place, changes would be necessary in existing methods of transport in order to ensure satisfactory delivery. The facilities at present available on the railways in Great Britain would be inadequate to ensure that the rapidly frozen products could be delivered satisfactorily and kept at the proper constant temperatures. Mechanically refrigerated vans for the delivery of these cuts from the central cold stores to the cold cabinets in the retailers' shops would have to be provided. Cold storage cabinets would have to be installed by retailers, and would have to be maintained at a temperature of not more than 15°F. These cabinets would probably not pay if used for the sale of meat only, and it would be necessary to work up a trade also in quick frozen fish, fruit and vegetables. This would all add considerably to the cost of distribution, and this extra cost could be met only if the public could be persuaded to pay a higher price for the carton meat. There is a further difficulty that the meat works in Australia are opened only during certain months of the year, and it would be impracticable to arrange for regular supplies of quick frozen meat to be exported throughout the year.

Designs for Banana Ripening Rooms.

A report dealing with co-operative investigations into the ripening and transport of bananas will shortly be issued as the Council's Bulletin 59. The investigations themselves were carried out in co-operation with the Committee of Direction of Fruit Marketing, Queensland, with the Universities of Queensland and Melbourne, and with the Railway Commissioners of Queensland, New South Wales and Victoria. Subsequent to the completion of the investigations, the Council's Section of Food Preservation and Transport has prepared detailed designs for rooms suited for the satisfactory ripening of bananas in Melbourne, Sydney and Brisbane.

These designs are based on the results of the above-mentioned co-operative investigations. Calculations for such rooms have shown that the external atmospheric temperature is a relatively unimportant factor in the determination of the amount of heat to be removed from the rooms, the important factors being the heat produced by, and the evaporation from, the bananas. From considerations of the necessity of maintaining at all times reasonably constant and uniform temperatures within the rooms, the application of refrigeration has been recommended in the designs under discussion. The various systems of refrigeration have also been examined and the possibility of automatic control of each system considered. A full description of the designs, with a sketch of the suggested ripening room, may be obtained by anyone interested on application to the Council.

The Poisoning of Cattle by Eating Saw-fly Larvae.—Investigation by Queensland Department of Agriculture.

Of recent years a rather peculiar problem has arisen over some hundreds of square miles in the Maranoa, Warrego, and Leichhardt districts of Queensland owing to the local cattle having a very marked appetite for the larvae of the saw-fly (*Pterygophorus analis* Costa). These larvae or so-called "caterpillars" feed in millions on the leaves of the broad leaf ironbark (*Eucalyptus melanophloia* F.v.M.). Subsequently, whether owing to over-population or to extreme heat in the defoliated trees, they leave the branches and cluster round the base of the main stems, where they die and putrefy in masses, which are often as much as 1 foot deep. Then they are ravenously eaten by cattle, with the result that many hundreds of the beasts die after showing symptoms such as irritability and other suggestions of toxin poisoning. The problem has been referred to the Council from time to time, but no investigations were initiated by the Council owing to the fact that the matter was under investigation by the Queensland Department of Agriculture. The results of the Department's work have recently been reported at length in the *Queensland Agricultural Journal* (Vol. 37, p. 41, January, 1932). As the matter may be of rather wide interest, the following note based on that article has been prepared:—

The cause of the deaths of the cattle is believed to be a toxin elaborated in the decaying masses of larvae and similar in nature to a ptomaine. The great increase in the number of larvae in recent years is possibly connected with the decrease in the number of opossums, which have been trapped and shot for their furs to a very considerable extent. An interesting point is that the consumption of living larvae either by cattle or opossums apparently leads to no harm. Opossums, for instance, consume a very large number of eggs and larvae at all stages with their normal diet, namely, the leaves of eucalypts.

The article discusses the reasons for the abnormal appetite of the cattle in the infected areas, and points out that it is probably due to their diet being deficient in some substance. From the resemblance of the symptoms to those of South African lambsiekte, it is considered that a phosphorus deficiency may exist. As a control measure a lick containing phosphorus either in the form of bone meal or ground rock phosphate has accordingly been suggested. Already some evidence of the efficacy of such a lick, to which common salt is also added, has been obtained.

Liberation of Insects to Control Oak Scale in Tasmania.

Scale insects have recently become somewhat troublesome to oak trees in Tasmania. The problem was mentioned to the Chief of the Division of Economic Entomology, Dr. Tillyard, a little time ago, and at his suggestion the permission of the Commonwealth Department of Health has now been obtained for the liberation in Tasmania of a small Chalcid wasp, *Habrolepis dalmanni*, which feeds solely on the scale and dies out when that pest is eliminated.

Habrolepis dalmanni is metallic green in colour, of very handsome appearance, and about 2 mm. long. The female is provided with a large and powerful ovipositor which it uses to prise up the tests of

Golden Oak Scale *in situ*, and by this means succeeds in depositing her eggs in the scales. The young larva hatches out inside the scale and devours it, pupating beneath the test.

The insect, like its host scale, is very rare in Europe, apparently owing to its efficacy in controlling its host, which is also regarded as a very rare insect indeed in England and various Continental countries. The planting of British oaks around Boston, United States of America, however, was the occasion of an accidental introduction of Oak Scale, which became a bad infestation, but later on the parasite *Habrolepis* also appeared on the same trees, and is now effectively controlling the outbreak. Some years ago Dr. Tillyard was responsible for the introduction of *Habrolepis* into New Zealand, where it also is doing good work.

The material which it is proposed to liberate in Tasmania is, as a matter of fact, being sent to Australia by the Cawthron Institute at Nelson, N.Z. The first consignment has already been sent to Launceston, but unfortunately most of the insects had emerged on the way down. A second consignment will be sent later.

The Cause of Caseous Lymphadenitis in Australia.

Note by H. R. Carne, B.V.Sc., Lecturer in Veterinary Pathology and Bacteriology, University of Sydney; and R. C. Cramp, B.V.Sc., Veterinary Officer, Metropolitan Meat Industry Board, Sydney. (From the Pathology Department, McMaster Animal Health Laboratory.)

Earlier investigations of caseous lymphadenitis in Australian sheep have indicated that the common cause of this disease in Australian sheep is the bacillus of Preisz-Nocard (or, according to more modern nomenclature, *Corynebacterium ovis*). A number of European investigators have recorded the occurrence of lesions which were identical in their macroscopic appearance with those of caseous lymphadenitis, due to the bacillus of Preisz-Nocard, but which were caused by other types of bacteria. Thus, *Bacillus pyogenes*, *Staphylococci*, *Diplococci*, and *Bacterium purificans* have been found responsible for caseous lymphadenitis of European sheep. A recent report from South America records the simultaneous presence of the bacillus of Preisz-Nocard and *Bacillus pyogenes* in caseous lesions of lymph glands of sheep in South America.

In the comprehensive study of this disease being undertaken in Australia, it was recognized that it was important to determine to what extent bacteria other than the bacillus of Preisz-Nocard were responsible for lesions of caseous lymphadenitis. To this end, during the years 1927, 1928, 1929, some 160 lesions from various lymphatic glands and internal organs of sheep have been submitted to bacteriological examination, which included direct microscopical examination of pus, cultural tests in aerobic and anaerobic media, and histological examination of lesions. All lesions except two (which were found to be sterile) contained the bacillus of Preisz-Nocard in pure culture.

It is concluded that caseous lymphadenitis of sheep in Australia is caused by pure infections with the bacillus of Preisz-Nocard, and that other bacteria which have been described as the cause of this disease in other countries occur but rarely, if at all, in Australian sheep.

These results narrow the problem considerably, for if a number of bacteria were responsible for this disease, it is possible that control of the disease might have necessitated separate measures against each of the causal bacteria.

Notes on Preliminary Tests on Certain Wheats and Oats.

By A. McTaggart, Senior Plant Introduction Officer, Division of Plant Industry.

During April, 1931, a comprehensive test of some 326 wheats, from various parts of the world, was set up. The wheats, after being weighed out into equal weights and treated with copper carbonate dust, were seeded in rows 25 links long, the rows being 2 links apart. Each variety or strain was seeded, in practically all cases, six times, the various replicates being distributed over the range (or area) in accordance with Fisher's Randomized Plot Method of testing varieties of farm crops. The soil on which the wheats were grown was for the most part poor, the greater portion consisting of clay loam, markedly deficient in organic matter. One end of the range, or a fourth of the area, however, consisted of somewhat better class soil—a reddish clay loam. Included in the test were some six varieties of Australian wheats, which were used to serve as checks in the testing of the imported varieties and strains. The highest yielding wheats of the test are listed, and briefly described below in the order of their average estimated yields per acre.

C P I No	Name or Serial No	Immediate Source	Original Source	Average Yield per Row (grams)	Estimated Average Yield per Acre (bushels)	Grain Description.
1200	1925 Crossbred—Marquis 108 x Kitchener 77	Dr Seager Wheeler, Ros-thern, Sask., Canada	Marquis - Ottawa, Kitchener—Dr Wheeler	589.4	43.31	Red, hard, translucent, small, even
1649	Florence x Gluyas 17	Stellenbosch - Elsenburg College of Agriculture, South Africa	Parents from Australia	578.5	42.51	Red, very hard, translucent
1412	Gluyas Early	Department of Agriculture, Pretoria, South Africa	Australia	575.1	42.26	White, hard, large
1106	C 1 7515 (Selection)	Office of Cereals, U.S. Department of Agriculture, Washington	Egypt	574.6	42.22	Red, semi-hard, mixed, translucent, and starchy
1107	C 1 8173 (Selection)	Office of Cereals, U.S. Department of Agriculture, Washington	Chile	572.3	42.05	White, somewhat soft, plump
(Check) 1428	Canberra American No 8	Australia Department of Agriculture, Pretoria, South Africa	U S A.	559.0 557.0	41.079 40.93	Red, hard, translucent
(Check) 1388	Waratah Roof Klein	Australia Department of Agriculture, Pretoria, South Africa	South Africa	542.3 530.3	39.85 39.41	Red, hard, for most part translucent
1389	Birdproof	Department of Agriculture, Pretoria, South Africa	South Africa	534.5	39.27	Red, hard, translucent
(Check) 1418	Nabawa Free Gallipoli Bearded Gluyas	Australia Department of Agriculture, Pretoria, South Africa	Australia	533.6 526.6 524.8	39.21 38.69 38.56	White, semi-hard

The highest yield per individual row was that of C.P.I. No. 1107 (C.I. 8173, selection from a wheat introduced into the United States of America from Chile). This individual row yielded at the rate of 74.29 bushels per acre. A specially favourable strip of soil, however, may have contributed appreciably toward the production of this high yield.

Oat Yields for Year 1931-32.

Some eighteen varieties were tested in rows 25 links long and 2 links apart. There were six seedings of each variety. The following shows the results for the six leading varieties:—

C.P.I. No.	Name	Average Yield per Acre (bushels)	Immediate Source	Original Source.
1049	Legacy (Ottawa 678)	55.92	Canada Experiment Farm, Ottawa, Canada	
(Check) 2046	Mulga Kherson (Selection No. 22)	55.51 54.47	Australia Rhodesia	U.S.A. and earlier Russia
2044	S.E.S. Oats (No. 49)	53.73	Rhodesia	Selection from "Burt" from U.S.A.
(Check) 1047	Sunrise Prolific (Ottawa 477)	51.97 50.80	Australia Canada Experiment Farm, Ottawa, Canada	

The soil in which these oats were grown was uniformly poor. All rows, of both oats and wheat, were inter-cultivated once—to check weeds.

New Grasses.

References have recently appeared in Australian and New Zealand newspapers to Woolly Finger Grass and Crested Wheat Grass as being worthy of trial in Australia. The Council desires it to be known that various strains of these grasses, among many others, have been introduced, and are being tested by the Plant Introduction Section of the Division of Plant Industry. The first-named grass was introduced from South Africa, where some 85 different strains or types are found. It is adapted to regions with warm climates and summer rainfalls. The second grass (Crested Wheat Grass) was introduced from Canada, whence it came from the western portion of the United States. The grass was originally introduced from south-western Asia, by the Office of Foreign Plant Introduction of the United States Department of Agriculture. It is adapted to regions with severe winters and relatively low annual rainfalls, which occur for the most part during the cooler seasons of the year.

The Better Design of Boxes.—The New Box-testing Drum of the Division of Forest Products.

In an endeavour to reduce the very considerable economic loss that occurs in Australia because of faulty and wasteful containers, the Division of Forest Products is about to undertake an investigation into the design of boxes and crates. Some idea of the importance of this work, and the scope for possible savings, may be gathered from the fact that Australia annually exports from 10 to 15 million boxes of commodities, such as butter, eggs, fruit (fresh, dried, and preserved), tinned meat, &c., in addition to which well over 50,000,000 containers per annum are required for domestic use. Thus, it will be seen that if even small savings could be made in the cost of the containers, important benefits would accrue to some of Australia's most important primary industries. Improvement in box and crate design, with the consequent reduction in loss due to damage to goods in transit is also of great importance to the railways, and to all industries making use of containers for shipping their goods.

The most practical method yet devised for this work is the revolving drum test, which was developed by the United States Forest Products Laboratory, and which is now used in investigations of this nature all over the world. A standard box testing drum (see Plate 6, Fig. 1) has recently been installed by the Division at its laboratories at Albert-street, East Melbourne. The drum, which was built by the Division's own staff, entirely of Australian material, is a hexagonal-sided machine, seven feet in diameter. When tests are being made, the drum is revolved slowly, at the rate of two revolutions per minute. Upon the six internal faces, hazards and guides are arranged in such a manner that, as the drum revolves, the box or crate slides and falls, striking on its ends, sides, top, bottom, edges, and corners, thus simulating the stresses, shocks, and rough handling of actual transportation. On one face of the drum is a projection upon which the container falls, to encounter a puncture hazard similar to that undergone by a box upon which another has dropped cornerwise.

For this method of testing, the box is loaded with its contents, or a substitute that produces the same effect, and the six faces, the cleats (if any), and the edges are numbered to facilitate recording the location and character of the failures as they occur. As the container moves on from one drop to the next, the observer notes and records each failure, and the number of the drop at which it occurred, a counter being provided on the machine for this purpose. The test is usually continued until the container becomes unserviceable, and either loses, or is unable to protect, its contents.

Laboratory tests bring out weaknesses in the design or construction of the box or crate very clearly, and on the basis of the observations made it is possible to design a container that for all practical purposes is equally serviceable in every feature, i.e., balance in construction. A balanced container will show an equal liability to failure in nails pulling from the wood, in wood pulling from the nails, and in splitting and breaking of ends, sides, tops, or bottoms. Most containers are excessively strong in one or more parts, but by balancing the design it is usually possible to effect considerable savings in weight and cost for a given strength, or vice versa, for a given cost, to increase considerably the strength and protection to the contents,

A very important part of the work being carried out by the Division is the designing of containers made of Australian grown timber. The timber used naturally has a considerable influence on the design of a box or crate, and it is accordingly proposed to carry out tests to determine the best and most economical design for boxes and crates using locally grown woods, so that they may compete on equal terms with containers made of imported material. If this line of work is successful, it will be of great value to the Australian timber industry, as more than £1,000,000 worth of timber is imported annually for the manufacture of the containers under discussion.

Should any one interested wish to have further details of the proposed work, the Division would be glad to provide them. Inquiries should be addressed to:—The Chief, Division of Forest Products, Council for Scientific and Industrial Research, 314 Albert-street, East Melbourne, C.2, Victoria.

The Manufacture of Tannin Extract in Western Australia—A New Australian Industry.

A little time ago the Division of Forest Products of the Council completed a comprehensive investigation in Western Australia of the possibilities of manufacturing a tannin extract from various barks that could readily be produced in large quantities in that State. The plant with which this work was carried out, and also its objects, were described in a previous issue of the Journal (Vol. 1, p. 285, 1928). A process of elimination showed that only two of the barks have possibilities in any way attractive from the commercial point of view, these being karri (*Euc. diversicolor*), and the kino-impregnated bark of the red gum or marri (*Euc. calophylla*). The former is a waste product at the karri mills, and contains about 18.2 per cent. of tannins. Investigations (which have also been reported at some length in a previous issue of the Journal, Vol. 2, p. 161, 1929), showed that it was possible to make a high grade extract, at a price that offered good prospects of commercial success. Some 20 tons of extract were prepared in the semi-commercial plant and tested, the results being satisfactory.

Karri bark has peculiar difficulties, but these proved to be overcome by a fairly simple process. The work on marri was not so complete, but it showed that there were good possibilities with this material. Previous workers aimed at a high percentage of extraction, but in the investigations of the Division this idea was dropped, and by aiming at the highest percentage extraction which gave a good grade extract, most of the troubles with marri bark were overcome.

As the result of this work, Messrs. Plaimar Limited, have now purchased the semi-commercial plant from the Council, and are re-erecting it near Perth, in order to manufacture and sell extract.

Thus, as a result of scientific investigation, a new industry, using a material hitherto entirely wasted, has been initiated in Australia.

Recent Publications of the Council.

Since the last issue of the Journal, the following Bulletins and Pamphlets of the Council have been published:—

Bulletin No. 53—"The Flying Fox (*Pteropus*) in Australia," by F. N. Ratcliffe, B.A.

This publication consists of a report of co-operative work conducted on behalf of the Council, the New South Wales Department of Agriculture, and the Queensland Home Secretary's Department. Since the earliest days of settlement, flying foxes (*Pteropus* spp.) have attacked cultivated fruit along the eastern coast of Australia, and control by means of shooting, poison gas, explosives, flame guns, poisoning in the orchards, &c., has proved unsatisfactory. The object of the investigation reported in the Bulletin was to obtain information as complete as possible in regard to the flying fox population in Australia, its size and extent, the relations of the different species one to another, the nature and cause of the migrations, the individual and collective habits of the animals, and the extent and value of the economic losses involved, with a view to determining whether it would be possible to suggest effective control measures or promising lines of further investigation to such an end. Four species of *Pteropus*, namely, *poliocephalus*, *gouldi*, *conspicillatus*, and *scapulatus* are involved and their total numbers amount to many millions. It is shown that the animal is mainly a blossom feeder, and that, contrary to the general belief, it is not a serious menace to the commercial fruit industry, although large losses occasionally occur, notably when soft fruits, such as figs, peaches, &c., are grown. The main conclusion of the report is that no proved method of mass destruction likely to be inexpensive in operation is known, and that indirect methods of control, for example by an introduced disease, are not practicable.

Bulletin No. 54—"Investigations on 'Spotted Wilt' of Tomatoes—II," by J. G. Bald, B.Agr.Sc., and Geoffrey Samuël, M.Sc.

This publication is a continuation of a previous Bulletin (No. 44). The development of a new technique of inoculation has enabled the properties of the virus giving rise to spotted wilt to be studied more extensively. The virus is very short-lived, losing most of its potency within three hours and the whole of it within six hours at room temperature. It is also very sensitive to heat, being killed by heating for ten minutes at a temperature in the neighbourhood of 42°C. It has been ascertained that the adult thrips of the species *Frankliniella insularis* are apparently unable to transmit the virus after feeding on a diseased plant, and it seems to be essential that they should have fed on a spotted wilt diseased plant during their larval life in order to become vectors of the disease. Spotted wilt has been experimentally transferred from the tomato to several other varieties of Solanaceous hosts, and the Iceland poppy, nasturtium and zinnia have been found to be naturally infected with the disease in suburban gardens, and have also been successfully inoculated under experimental conditions. It is possible that the virus may be carried over in these plants during the seasons when tomatoes are not growing.

Bulletin No. 55—"The Basal (Standard) Metabolism of the Australian Merino Sheep," by E. W. Lines, B.Sc., with the assistance of A. W. Peirce, B.Sc.

This publication reports the results of fundamental studies into the standard metabolism of the merino sheep as influenced by age, sex, and nutritive level. The method used was to measure the actual gas exchange of the animal in an open circuit apparatus. The work is of considerable importance from the practical point of view in connexion with the development of the most economical formulae for fodders in times of drought. The basal metabolism of an animal being known, the minimum amount of energy-producing food to keep it alive when the natural pastures have been exhausted can be derived, and with the data available as to the energy contained in different foodstuffs, their digestibility, and their price, the cost of the most economical hand-feeding in any given locality can readily be calculated.

Bulletin No. 56—"A Soil Survey of Blocks A, B, C, D, and F. Renmark Irrigation District, South Australia," by T. J. Marshall, B.Sc.Agr. and P. D. Hooper.

The Bulletin contains the results of a soil survey of the Renmark irrigation area, portion of which had previously been surveyed and the results published as Bulletin 42. The various soil types (eleven in number) are discussed at length in relation to their behaviour on irrigation and cultivation.

Bulletin No. 57—"Infectious Entero-toxaemia (the so-called Braxy-like Disease) of Sheep in Western Australia," by H. W. Bennetts, D.V.Sc.

The results of an extensive investigation into this problem carried out in co-operation with the Western Australian Department of Agriculture are given. The disease is an acute toxæmia of sheep following the rapid multiplication of a specific toxicogenic anaerobic bacterium, which has been named *B. ovitoxicus*, within the contents of the small intestine. It has a seasonal incidence and affects chiefly sheep in good condition. The onset of death is rapid, often without premonitory symptoms. The results obtained in the field with *B. ovitoxicus* ana-culture are very promising and active immunization with vaccine of this type offers a most hopeful method of control. In the meantime, certain measures of flock management have been suggested and these may help to lower the mortality rate. Evidence suggestive of the ultimate development of a natural acquired immunity is rather encouraging.

Bulletin No. 58—"The Life Cycle of *Stephanurus dentatus* (Deising), 1839: The Kidney Worm of Pigs," by I. Clunies Ross, D.V.Sc., and G. Kauzal, D.V.Sc.

The Bulletin deals with investigations carried out on a co-operative basis by the Council and the University of Sydney, one of the investigators, Dr. Kauzal, being located at the Veterinary School of the University as a result of finances made available to the University by the Pastures Protection Board of New South Wales. The kidney worm of pigs is of considerable economic importance, because heavy infestation frequently leads to condemnation of the carcass, while even moderate infestation may lead to rejection of the carcass for export to Europe. There is evidence that the number of infestations (and also their severity in individual pigs) is increasing. The life cycle of the parasite has been determined and reported at length. Climatic conditions prevent its occurrence in localities some distance south of Sydney. Satisfactory control measures have been developed and are discussed at length. Briefly, they involve the avoidance of damp areas

in the yards, or if any such areas are unavoidable, their spraying with kerosol at the rate of 10 gallons of a 5 per cent. solution per 100 square yards.

Pamphlet No. 23—"Refrigeration Applied to the Preservation and Transport of Australian Foodstuffs," by J. R. Vickery, Ph.D.

For some time past, the Council has recognized that the whole question of systematic investigations in this field of work is a matter of very considerable importance to Australia's primary industries, in connexion with the export of perishable foodstuffs, and with the development of land settlement and the problem of finding new markets. As a preliminary to the formation of its Section of Food Preservation and Transport, it obtained from Dr. J. R. Vickery a report on the matter. His report has been published as Pamphlet 23. The main recommendations are to the effect that it would be desirable (i) to initiate some work in Queensland, more particularly on the chilling of beef, and later on in regard to tropical fruits, and (ii) to initiate some work at Melbourne in regard to the storage and transport of fruit such as apples, pears, &c., which are being produced in large quantities in the southern States.

Pamphlet No. 24—"The Preservative Treatment of Fence Posts," by J. E. Cummins, M.Sc.

This pamphlet contains information primarily intended for farmers and the man on the land in general. The quantities of durable timbers now available for fence posts in farming areas have become very limited. Information is given in regard to methods whereby the life of non-durable fence posts can be considerably extended at comparatively small cost. The wide adoption of the practice of preserving fence posts by some such methods as those outlined in the pamphlet would result in the utilization of considerable amounts of timber that are now wasted in Australia.

Forthcoming Publications of the Council.

The following publications of the Council are now in the press:—

Bulletin No. 59—"The Ripening and Transport of Bananas in Australia," by W. J. Young, D.Sc., L. S. Bagster, D.Sc., E. W. Hicks, B.A., B.Sc., and F. E. Huelin, B.Sc.; and in part by R. A. Holloway, B.Sc., B.E., and O. P. Barr, B.E., of the New South Wales Government Railways.

Bulletin No. 60—"Studies in Supplementary Feeding of Merino Sheep for Wool Production," by Hedley R. Marston.

Bulletin No. —Radio Research Board—Report No. 2—(1) The State of Polarization of Sky Waves; (2) Height Measurements of the Heaviside Layer in the Early Morning, by A. L. Green, M.Sc.

Bulletin No. —Radio Research Board—Report No. 3—The Influence of the Earth's Magnetic Field on the Polarization of Sky Waves, by W. G. Baker, B.Sc., B.E., and A. L. Green, M.Sc.

Bulletin No. —Radio Research Board—Report No. 4—A Preliminary Investigation of Fading in New South Wales.

Pamphlet No. —"The Irrigation of Horticultural Community Settlements," by A. V. Lyon, M.Agr.Sc.

Pamphlet No. —"Termites (White Ants) in South-eastern Australia," by G. F. Hill.

Journal of the Council for Scientific and Industrial Research.

Vol. 5.

MAY, 1932.

No. 2.

Observations on the Resistance of Sheep to Infestation by the Stomach Worm (*Haemonchus contortus*).

By I. Cluntes Ross,* D.V.Sc.

1. Introduction.

In a recent article, Stoll (1929) records the development in two lambs of a very marked degree of resistance to infestation with *Haemonchus contortus*, following an initial light experimental infestation in the case of one animal and subsequent continuous exposure to natural infestation on restricted pastures of both animals, as the result of eggs voided by the experimentally infested lamb. Initially, each showed evidence of a normal and progressively increasing infestation with *Haemonchus contortus*, as indicated by steadily rising egg production, which reached as much as 13,600 per gm. of faeces in one case, and 10,000 per gm. in the other after three months. After remaining at this peak for about one month, egg production rapidly declined, and ceased a few weeks later, four months after the first eggs of the parasite appeared in the faeces. Subsequent exposure of these animals, in the one case to heavy experimental infestation, and in the other to repeated risk of natural infestation on heavily contaminated pastures, failed to set up any appreciable degree of fresh infestation, it being found that larvae experimentally administered were rapidly voided in large numbers in the faeces.

On a post-mortem examination, both animals were found to have a very slight infestation with *H. contortus*, individual worms being smaller than normal, and showing evidence of poor egg production. Stoll concluded from the evidence thus obtained that *Haemonchus* infestation of sheep, provided it is not so heavy as to overwhelm the resistance of the animal and lead to its death but yet of sufficient severity to provoke an active immunological response, will result in the development of an immunity or resistance which may be absolute.

In view of the fact that our personal experience with *H. contortus* infestation in Australia, both in the field and under experimental conditions, presented many features at variance with these conclusions of Stoll, it was thought advisable to put forward the following observations in regard to this problem.

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2. Field Observations.

Station A.

In the early summer of 1928, the writer had occasion to visit a large Queensland station, some 80,000 acres in area, on which the normal carrying capacity was about 40,000 sheep. This property was situated in an area noted for heavy infestation with *H. contortus*, and, to a lesser degree, with *Oesophagostomum columbianum*. In the course of investigations carried out at this station, a number of aged ewes which had been bred and run continuously on the property for four or more years were autopsied. Of eight thus examined, six showed degrees of infestation with *H. contortus*, varying from 400 to over 1,000 worms, while the other two were completely negative. A number of lambs, which were less than six months old, were also examined on the same property, and these all showed some hundreds of worms, the numbers being comparable to those found in the ewes examined, with the exception of the two negative cases. On this property, worm infestation is so heavy and serious that, until the introduction of a system of periodic drenching with carbon tetrachloride, in 1928, losses in the late summer and autumn amongst young sheep reached from 1,000 to 5,000 per annum, while lambing ewes also suffered considerable mortality.

In this case, therefore, it is seen that, though the ewes had been continuously exposed to recurring infestation for a number of years, the majority of those examined showed considerable degrees of infestation, such infestations being comparable to those of lambs suffering their first season's infestation. It should be mentioned also that these cases were examined early in December, whereas worm infestation becomes worse during the later summer months and early autumn, so that it might be expected that the animals would show even heavier infestations later in the season.

Station B.

This was a similar Queensland property, in the same district as Station A, but larger in extent (200,000 acres), and carrying normally about 70,000–80,000 sheep. Prior to 1928, it had been practically impossible to rear young sheep on this property, and at that time it was almost wholly stocked with aged wethers, which had been brought in from worm-free country further to the west. This station was re-visited in 1930, some years after breeding had been resumed. Ten aged "culled" wethers, from nine to eleven years old, which had been running on the property continuously for from four to six years, were autopsied. Eight showed from 500 to more than 1,000, but two less than 100 *H. contortus*. Two four-tooth sheep, three two-tooth sheep, and four lambs were also autopsied, and all showed moderate to heavy degrees of infestation with *H. contortus*, these infestations on the average being no heavier than those of the aged wethers.

Therefore, on these stations both ewes and wethers had been exposed to continued infestation over a number of years without any marked resistance (as determined by the degree of infestation), becoming evident, except in a minority of aged animals. This would suggest either—

1. That the sheep were subjected to repeated infestation which was not sufficiently heavy to call forth a strong degree of resistance—in the circumstances most unlikely; or

2. that any resistance developed was evanescent, and did not last from season to season; or
3. that the production of such resistance as Stoll describes is in no way constant, and possibly is determined by factors additional to those he suggests.

In addition to these observations in the field, the following experimental data were obtained in the laboratory.

3. Experimental Observations.

The following observations were made on individuals of four groups of sheep which previously had been exposed to artificial infestation with *H. contortus* in connexion with tests of the anthelmintic properties of certain drugs given in licks and in drinking water. It may be noted that none of these drugs appeared to have the slightest effect on the parasites, sheep in all lots that received such drugs showing as regular and heavy degrees of infestation, and suffering as much mortality as those in the untreated control group.

For the purpose of this paper, these sheep may be considered as re-grouped according to age and breed:—

Lot A.—Four ewes, three being aged (S 43, 44, and 45), and the other a four-tooth (S 78).

Lot B.—Six merino lambs eight to twelve months old (S 72-77).

Lot C.—Six Lincoln cross merino lambs eight to twelve months old (S 80 to 85).

Lot D.—Four merino lambs three months old (S 91-94).

All animals were kept in concrete-floored yards, which were swept and hosed out daily. Food, which was supplied in troughs, consisted of oaten chaff, crushed oats, and bran in the morning, and lucerne hay at night.

(i) *Degree of Worm Infestation at Commencement.*

At the beginning of the trial, all sheep in Lot A were found to have a heavy degree of infestation with *H. contortus*, faecal cultures showing over 90% of this species. One animal (S 43) showed marked pallor of the visible mucous membranes, while two others (S 44 and 78) showed definite, but less marked, signs of clinical haemonchosis, though the degree was not determined by erythrocyte or leucocyte counts.

Lot B.—All animals in this group were found by faecal culture to be heavily infested with *H. contortus*, cultures showing over 90% of larvae of this species. Egg counts of the faeces of each sheep by the Stoll method showed from 6,000 to 33,000 eggs per gm.

Lot C.—No animal in this group had a higher egg count than 900 to 2,000 eggs per gm., while larvae consisted of approximately equal numbers of *H. contortus* on the one hand, and *Ostertagia* spp. and *Trichostrongylus* spp. on the other. No animal showed any clinical signs of haemonchosis.

Lot D.—Repeated culture and egg counts of this group showed no evidence of infestation with *H. contortus* or other helminths, except *Strongyloides* spp. No animal showed any clinical signs of haemonchosis.

(ii) *Nature of Treatment Given.*

Lot B was treated with 1 cc. tetrachlorethylene per sheep on the 22nd December, 1930, and Lots A and B with 2 ccs. carbon tetrachloride on the 29th December, 1930. Subsequent faecal culture and egg counts showed a marked decrease in the degree of infestation with *H. contortus* in all animals in both these groups. In Lot A, all clinical evidence of haemonchosis disappeared in from two to three weeks, while in Lot B, cultures showed only from 5% to 32% *H. contortus* one month after treatment, and counts ranged from 600 to 4,000 eggs per gm. of faeces. Lot C continued to show only light infestation, and Lot D to be negative (except for *Strongyloides* spp.).

Artificial infestation of all lots was begun on the 13th February, 1931. Each sheep was drenched with larval cultures containing not less than 95% *H. contortus*, from 500 to 1,000 larvae being administered each week to Lots B, C, and D until the 22nd May, 1931, when a total of 6,500 larvae had been given to each animal. Larvae were administered to Lot A at the same rate as to Lots B, C, and D until the 16th April, 1931, after which from double to four times the number were given at each drenching, so that on 20th May, 1931, each of these sheep had received 11,000 larvae.

(iii) *Observed Effects of Infestation.*

From four to five weeks after artificial infestation was begun all sheep in Lots B, C, and D showed progressively increasing degrees of infestation, and by 8th April all sheep in these lots showed over 90% of *H. contortus* larvae in cultures, there being little difference in any of these groups. With Lot A, however, though there was a high percentage of *H. contortus* larvae in cultures, and though one sheep showed a count of up to 5,000 eggs per gm. from week to week, in no case was there evidence that any steady progressive increase in infestation was taking place. On the 27th April, 1931, S 75 (Lot B) died after suffering from intermittent diarrhoea for about ten days. This animal could not be autopsied for some 24 hours, by which time any *H. contortus* were dead and degenerated. It was not considered, however, that death was due to haemonchosis, though prior to death the visible mucus membranes were markedly anaemic.

At this time, some sheep in Lots B, C, and D were showing counts of up to 20,000 eggs per gm., and it was evident that very heavy infestations had been established. During the next three weeks, a number of clinical cases of haemonchosis began to develop in Lots B, C, and D, and in these lots nearly all animals showed counts of from 20,000 to 60,000 eggs per gm., but no sheep in Lot A (adults) showed any increase in infestation, and all made satisfactory gains in weight.

From thirteen to seventeen weeks after infestation was begun the following animals died or received anthelmintic treatment when showing marked symptoms of acute haemonchosis or other evidence (egg counts and larval cultures) of heavy infestation:—S 73, 74, 75, 76, 77, 81, 82, 83, 84, 85, 91, 92, 93, 94, all of which were in either Lot A, B, or C. Only three animals (S 73, 80, and 84) out of these three lots remained in apparently normal health up to the 18th week. S 84, however, though it showed no pallor of the mucus membranes, and appeared lively and in normal health, gave egg counts repeatedly reaching as high as 20,000 to 40,000 eggs per gm., over 95% of larvae in cultures being *H. contortus*. S 73, though also in good condition, was

shown by repeated egg counts (up to 33,000 eggs per gm.) to have an equally heavy infestation. In both these animals, therefore, in spite of their apparent resistance, infestations comparable in intensity to those in more obviously affected animals were set up. In the case of S 80, egg counts were as low as 2,600 to 4,800 eggs per gm., yet on autopsy in the 23rd week (the sheep being kept under the same conditions as during the trial) this animal was found to have from 500 to 1,000 *H. contortus* (exact number not counted)—a moderately heavy infestation. In this animal, the egg counts had remained surprisingly low, considering the degree of infestation found.

The routine examination of sheep was discontinued after 18th June, 1931 (eighteen weeks after infestation was begun), when faecal cultures of the adult sheep, S 78, 45, 43, and 44 (Lot A), were either negative (S 43 and 44) or showed very few *H. contortus* larvae (S 78, 45).

On autopsies between 18th to 24th August, 1931, these sheep contained the following *H. contortus*:—S 78, 4; S 45, 154; S 43, none; and S 44, none.

4. Discussion.

In the above observations on animals artificially infested with *H. contortus* it is seen that all four ewes (one four-tooth and three aged), which had been freed to some extent from an earlier and heavy infestation by medicinal treatment, subsequently proved refractory to attempts to re-infest them. A group of lambs (Lot B), also freed to some extent from heavy infestation, all proved as susceptible to re-infestation as two other lots (C and D), one of which had had a previous very light infestation, and the other no previous infestation.

On the other hand, in the natural infestations recorded, though the aged ewes and wethers examined had been exposed to infestation from year to year, only a small minority showed evidence of an absolute resistance to infestation, the majority still harbouring a considerable number of worms.

In contrast, we have such phenomena as the self cure and subsequent resistance to re-infestation on the part of lambs, as recorded by Stoll (loc. cit.), the marked individual resistance, as noted by ourselves, of adult sheep in lots experimentally infested with *H. contortus*, and, as in Stoll's cases, the complete self cure of heavily infested animals without treatment.

It would appear, therefore, that the degree of resistance to infestation with *H. contortus* is influenced by a complex of forces of the individual importance of which we are not yet aware. Among such forces, the following suggest themselves:—natural resistance, age resistance, an acquired resistance due to a prior infestation, and nutritional factors.

(i) *Natural Resistance.*

There is at present little experimental evidence that individual young sheep, not previously exposed to infestation, have any natural resistance to infestation, that is, a resistance inherent in the individual, and appearing in animals of the same age and breed maintained under identical conditions. Fourie (1931), however, endeavoured to infest lambs artificially with pure cultures of *H. contortus*, and though these lambs are stated never to have been exposed to infestation previously,

he found that in a group of 38 lambs nine fatal cases of haemonchosis were set up, six heavily infested animals recovered, while 23 resisted and did not show the effects of infestation. It is not stated whether the resistant 23 animals failed to become infested, or merely proved resistant to the effects of any infestation set up; but, since enormous numbers of larvae were administered (up to 50,000) in the cases recorded in detail, it would appear that the degree of resistance varied very greatly. (No egg counts of individual animals are given.) That this might be due in some cases, however, not to resistance to the actual infestation, but rather to resistance to its effects, is suggested by the case of S 73 and 84 above, which, though very heavily infested, showed no clinical evidence of haemonchosis.

We have recorded recently (Ross, 1931) that in two newly-born worm-free lambs, receiving 1,000 *H. contortus* larvae each, 48.5% and 6% of larvae developed respectively. But in this case the larvae were administered in a single dose to each lamb—a highly unnatural procedure—so that, having regard to the variable course which fluids may follow in reaching the abomasum when given to sheep by the mouth, it cannot be accepted that this variation reflected the true degree of resistance in the two animals. In connexion with hookworm infestation in the dog, it has been shown by Herriek (1928) that, even in puppies exposed to their first infestation, the number of larvae developing varies as widely as 6% to 60%.

There seems some ground, therefore, for believing that individual natural resistance may play an important part in determining the degree of infestation set up naturally or artificially in lambs.

(ii) *Age Resistance.*

Among stockmen and others it is a commonplace that aged sheep, with the possible exception of lambing ewes, suffer much less from the effects of worm infestation than lambs, it being frequently said that, once a sheep becomes a two-tooth (eighteen months old approximately), there is little likelihood that it will show marked effects of worm infestation. There is, however, little experimental evidence that such sheep are less susceptible to infestation than young lambs, though they certainly show less marked effects of such infestation. Again, under natural conditions, it is impossible to determine to what degree any resistance shown is due to age, and to what degree to the effects of a prior infestation. The great majority of sheep in Australia exposed to infestation when aged have already been infested in their youth. We have recorded, on the other hand, that aged animals killed in the field, as well as in Lot A above, may show considerable or even heavy degrees of infestation.

(iii) *Acquired Immunity.*

There appears little doubt that at least a temporary and partial immunity to infestation does frequently follow infestation, such resistance commonly being encountered where attempts are made experimentally to infest lambs which are not worm-free. In most instances, however, such resistance is not absolute, since light infestations are maintained throughout, or may be set up. Acquired resistance, if produced, must evidently be of short duration, at least in many cases, in view of the heavy infestations met with in sheep of all ages in areas of heavy enzootic infestation, though only the younger animals may exhibit obvious effects of parasitism.

McCoy (1931) has also found in the case of dogs that, though such resistance is developed in animals exposed to repeated infestation with *Ancylostoma caninum*, so that they may throw off heavy infestation and prove temporarily refractory to re-infestation, yet after a lapse of time, some may be re-infested once or even twice.

In the sheep, it is probable that a greater degree of resistance may be developed in older and stronger sheep than in lambs, as suggested by the variation in susceptibility to re-infestation of Lots A and B above.

The production of a strong and lasting acquired resistance to *H. contortus*, particularly if persistent, would be of interest, in view of the fact that, at the present time, the most striking examples of either age immunity, or acquired immunity to metazoan parasites are perhaps those in which there is a suggestion of abnormal host-parasite relationship, such as the age immunity to *Syngamus tracheae* in chickens (Ransom, 1921), and acquired immunity to the trematode infestation with *Nanophyes salminicola* (Donham, Simms, and Miller, 1926) in the dog. We have recently suggested (Ross, loc. cit.) that *H. contortus* is specifically adapted to survival in the sheep rather than the ox, and the host-parasite relationship with the former is the normal one. Were this so, it would perhaps be expected that either an age immunity or a prolonged and absolute acquired immunity would be less likely to be developed than if the host-parasite relationship were abnormal. This may be contrasted with the difficulty which Monnig (1926) found in infesting Merino sheep over two years old with *Trichostrongylus rugatus* and *T. instabilis*, while aged Persian sheep remained much more susceptible. Here, it is highly probable, is a difference in immunological response, due to the variation in the host-parasite relationship in the two breeds.

It may be stated, therefore, that, though an acquired immunity to *H. contortus* not infrequently follows a heavy degree of infestation, such resistance, even in aged animals, may be of such temporary duration that the animals may subsequently be re-infested.

(iv) *Nutritional Factors and Resistance.*

It is very generally held that nutritional factors exercise a vital influence on the degree of infestation of sheep with *H. contortus*. Here again, however, resistance to infestation is commonly confused with resistance to the effects of infestation. Thus the fact is frequently cited that sheep which are apparently in normal health when feed is young and nutritive in the spring and early summer, develop marked haemonchosis when it dries off in the late summer, autumn, and even winter, and so becomes less nutritious. This, however, may be due, not to the fact that animals then become more susceptible to infestation, but either to the fact that infestation has been steadily built up throughout summer and autumn, and ultimately reaches a degree sufficient to produce symptoms of haemonchosis, or to the fact that animals in a poor nutritive condition show the effects of infestation more markedly than those infested to an equal degree, but adequately nourished. It is not improbable, however, that the acquired resistance of sheep may be weakened, or entirely dissipated, by their subjection to impaired nutritive conditions.

Foster and Cort (1931) have recently demonstrated experimentally that the acquired resistance of dogs to infestation with *Ancylostoma caninum* may be readily removed by placing them on deficient diet, and no less rapidly restored by an adequate diet. If the degree of susceptibility of sheep to *H. contortus* and the duration of acquired resistance are affected in a similar manner, many observed facts would be explicable, including the greater susceptibility of Lot B compared with Lot A (see above), since the nutritive requirements of young sheep being more exacting than those of aged animals, they might under field conditions obtain comparatively less adequate nutrition, and the production of a degree of resistance be correspondingly impaired. In this also would lie the explanation of the frequent heavy infestation of aged sheep in areas of heavy enzootic infestation, especially under unfavorable seasonal conditions. There would possibly still be contradictions, such as the absolute immunity enjoyed by a minority of aged animals in such areas, but these might well be animals in which already a renewal of resistance has been acquired temporarily, or which exhibit an idiosyncratic natural resistance.

These facts have a very important bearing on questions of the control of worms in sheep, and particularly the safeguarding of young animals, since it is evident that aged animals may be heavily infested with *H. contortus*, although not necessarily exhibiting any effects of such infestation, and may thus serve seriously to contaminate pastures simultaneously or subsequently grazed over by young sheep.

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Research on Bees: A Progress Report.

By G. A. Currie,* B.Sc., B.Agr.Sc.

A brief note in regard to the objects of the Council's investigations on bees, and in regard to the grant from the Rural Credits Development Fund that had been made available for the assistance of that work, was given in a previous issue (see this *Journal* 4 : 253, 1931). Attention was drawn in that note to the fact that the Australian bee industry is responsible for a production worth £100,000 per annum, based on official statistics alone, that Apiarists' Associations consider the industry annually produces very much more than that amount, as there are numbers of beekeepers holding relatively small areas from whom no statistical returns are obtained, and that the industry is apparently capable of considerable extension if certain disabilities, including dwindling, can be overcome. Although the onset of cold weather has now put an end to the study of certain phases of the investigations, some advances in the work have already been made. An account of these is given in the article that follows.—Ed.

Summary.

The problem of D.T. or pollen deficiency disease in Australia is being investigated by the Council in conjunction with the Victorian Apiarists Association. The problem seems to consist of finding an efficient substitute for pollen, to be given to the bees during a period of pollen shortage in the field. The research is divided into three parts—

- (1) Laboratory.—Finding a substitute for pollen which will lead to the development of the brood food glands in the head of the young worker adult.
- (2) Insectary.—Testing substitutes in the hive to see if they can develop the larvae during the period of progressive feeding to the adult stage.
- (3) Testing substitutes in the field on a commercial scale during a period of pollen shortage.

The laboratory stage is fairly well advanced. Yeast, casein, and certain mixtures of these, with other substances, have been shown to develop the brood food glands.

The insectary work is showing indications of success, but field work has not yet been commenced, owing to the non-development of the trouble during the past two seasons.

1. Introduction.

In certain parts of Australia it has been observed that in dry years, generally during the months of January, February, and March, bee stocks have dwindled rapidly and died out, although honey has been plentiful. The areas concerned are chiefly those in which yellow-box, *Eucalyptus meliodora*, is one of the main honey-bearing trees. Mr. Beuhner† and other apiculturists have observed that under such conditions the pollen from yellowbox flowers and from certain other Eucalypts flowering at the same time is not available to the bees owing to its stickiness. Further, dry seasons prevent ground flora from flowering, and a condition arises in which no pollen for brood rearing is available to the bees, so that, as the old field workers die off from natural causes, no young ones are reared to take their places. This dwindling was called D.T. (Disappearing Trick), or deficiency disease.

* An officer of the Division of Economic Entomology, C.S.I.R.

† Late Apiculturist to the Victorian Department of Agriculture, and now Secretary, Victorian Apiarists Association.

Several endeavours have been made by various people in the past to have some research work initiated with a view to a control of the problem. The name of Mr. Tarleton Rayment comes readily to mind in this connexion. Further, in 1928, the New South Wales Apiarists Association and the Victorian Apiarists Association both passed resolutions desiring that research into this problem be undertaken. Two years later, the Victorian Association succeeded in having a grant from the Rural Credits Endowment Fund of the Commonwealth Bank made available to the C.S.I.R. for research into the problem.

Many methods of overcoming the pollen deficiency had previously been considered. Amongst these were—

- (1) The introduction into the Australian flora of trees known to flower and produce pollen at the season of shortage.
- (2) The transferring of pollen-filled combs from one district to another.
- (3) The collection and storage of natural pollen during periods of abundance against periods of shortage.
- (4) The cultivation of low growing plants for pollen production under irrigation.

All of these were rejected as impracticable. There only remained further researches into the possibilities of efficient pollen substitutes.

When C.S.I.R. took up the problem, it was decided that Mr. Beuhne's estimate of what the problem was, viz., one of pollen deficiency, should be accepted as the starting point of the investigation, and that the first definite aim should be to try out possible pollen substitutes exhaustively.

Arrangements were made for the field work to be undertaken by Mr. Beuhne, and the author was allowed to devote a part of his time to the laboratory work. The Council provides without charge the use of the laboratory, microscopes and other instruments, insectary space, and electric power and light.

2. Pollen Substitutes in General.

For many years, beekeepers all over the world have fed various substitutes for pollen to their bees in times of scarcity. Rye flour, wheat flour, pea flour, and Mellin's food are typical examples of the substitutes used, and it is well known that the bees readily collect and store such substances. However, critical tests have not borne out the claims made for these substances, and it appears unlikely that brood has ever been successfully reared to the adult stage wholly on these substitutes (Parker, 1926)*. On the other hand, some evidence has been obtained in recent years that milk and sugar fed to bees in spring may lead to vigorous brood rearing when pollen is scarce (Winson, 1930)†. There are many sides to the use of pollen in the hive to be met by a substitute. Thus, to be successful, a substitute must be—

- (1) A dry powder;
- (2) not repellant to bees, so that they will collect and store it;

* Cornell Univ. Agr. Expt. Sta., Ithaca, N. Y., *Memor.* 98.

† *American Bee Journal*, September, 1930, p. 434

- (3) chemically constituted so that it will stimulate the brood food glands of the young adults to produce food for the queen, and for the young larvae during the period of mass feeding; and
- (4) so constituted that, when fed mixed with honey to the larvae in the period of individual feeding it will allow them to develop to the fully functional adult stage.

Bees also use pollen in the cappings of the brood cells, but it is not certain if it is an essential constituent of these.

Dr. Soudek (1927)* of Czecho-Slovakia, has demonstrated that yeast and egg albumen can produce development of the brood food glands, but, in the state in which they are ordinarily procurable, they do not fulfil the other conditions of an ideal pollen substitute. After all the above conditions have been met, it must be remembered, too, that any pollen substitute to be used commercially must be cheap enough to warrant its use. Bees may use up to 7 oz. of pollen a day in a big colony at the height of brood rearing, but requirements normally would be much smaller than this.

3. Plan of Present Investigations.

The work now under review was planned out in the following sequence :—

- (1) A check of the effect of known pollen substitutes and any new ones on the development of the brood food glands of young workers in an incubator.
- (2) A test of these substitutes on a colony basis in an insectary where pollen is not available, to determine if brood can be reared to the adult stage.
- (3) Following (1) and (2) above, a field test of any promising substitutes, the test to be carried out on a commercial scale and during a period of pollen deficiency.

When work was commenced, the first necessity was a supply of bees to draw from, so some hives of Carniolans were purchased late in 1931. From these, brood comb containing capped worker cells has been continually drawn. An incubator maintained at about 31° C. is used in the laboratory, the pieces of brood comb from which the young workers emerge being kept in gauze-topped glass jars. As the adults emerge, they are put into small boxes provided with wire-gauze covers, and the food for the bees is placed in pieces of comb, which are sealed to the bottom of the boxes. At first, the pollen substitute was mixed with sugar syrup and put into the cells, so that the bees were compelled to take it. Later, it was found that when a dry pollen substitute was used, it could be packed in the outer cells like pollen, and the syrup placed in the cells in the centre. Under these conditions, the young adults feed readily on the dry substitute.

* Bull. de l'Ecole Supérieure d'Agronomie, Brno. R.C.S.

4. Development of Brood Food Glands.

Experimental Series 1.

In each case, 25 bees or more were used for a single experiment, and the results were as follows:—

Substitute.	Results.	Remarks.
Casein	No development	
Casein and yeast	No development	
Egg albumen	Slight development ..	Bees died off early
Egg albumen and yolk	Slight development ..	Bees died off early
Gelatin	No development	
Pollard of wheat	No development	
Pollen (Control)	Fair development	
Pea flour	No development	
Pea flour and yeast	Slight development	
Pollard and yeast	No development	
Syrup only (Control)	No development	
Yeast	Fair development	

Experimental Series 2.

Substitute.	Results.	Remarks.
Casein	Slight development	
Casein and yeast	Good development ..	Bees healthy and lived to 32 days
Casein and cystine	No development	
Casein and pea flour	No development	
Cystine	No development	
Cystine and pea flour	No development ..	Probably died from syrup becoming too concentrated
Cystine and peptone	No development	
Milk, dried (Trufood)	Fair development	
Milk and yeast	Fair development	
Peptone	No development ..	Bees died off very rapidly (within 2 days), except when solution of peptone in sugar syrup was very weak, when they lived up to 7 days
Pollard (wheat offal)	No development ..	Bees collected on their legs as if natural pollen
Syrup only	No development	
Yeast (dried and pulverized in mortar)	Fair development ..	Bees healthy and active

Experimental Series 3.

Substitute.	Results.	Remarks.
Casein 1 part, yeast 1 part ..	Fairly good development	
Casein 5 parts, yeast 1 part ..	Fairly good development	
Casein 10 parts, yeast 1 part ..	Fairly good development	
Casein 15 parts, yeast 1 part ..	No development	
Casein 20 parts, yeast 1 part ..	Fair development	
Milk (dried) 1 part, pea flour 2 parts	Fair development	
Pollard 8 parts, yeast 1 part ..	Fair development	

Experimental Series 4.

Substitute.	Results.	Remarks.
Casein only	Fair development	
Casein 25 parts, yeast 1 part ..	Fair development	
Casein 1 part, egg albumen, dry powder, 1 part	Slight development	
Casein 10 parts, dried milk 1 part, yeast 1 part, pollard 1 part	Fair development	
Egg albumen, fresh	Fair development	
Egg albumen, dry (powdered) ..	No development	
Egg albumen, dry (powdered), 1 part, dried milk 1 part	Fair development	

The results, as can be seen, are not regular, but the general conclusions are that yeast alone or in admixture with various cheaper protein foods can stimulate the brood food glands to active functioning.

Another most important finding is that casein alone can lead to development of the pharyngeal glands. This substance is cheap enough to warrant its use, and being a dry powder it is easily stored and fed to the bees. Probably this substance can be used to combine with yeast and pollard to give an effective substitute. Experiments with these substances are at present in progress.

When pollard was used it was noticed that the bees generally died off fairly early (about ten days old), and that they died with the abdomen distended with gases. It seems probable that substitutes containing much starch cause digestive disorders, as it is well known that the bee cannot digest starch.

From the point of view of cheapness it would be desirable to add as much pollard as possible to any mixture, but it would appear that the foods richer in protein and poorer in starch are more healthy for the bee. Further series of tests will be set out to determine the cheapest effective substitute.

5. Feeding of Larvae.

The larvae newly hatched from the egg are fed by the "nurse" bees with the "brood food" from the glands referred to above. This "mass feeding" is carried on for the first two and a half days of the larval life, when the young larvae float on the brood food and absorb it. When plenty of young adults are present (four to ten days old), and sufficient pollen for their feeding is present in the hive, the supply of brood food is lavish.

After the period of "mass feeding," the larvae enter the period of "progressive feeding," during which period they are fed by the very young adults on pollen mixed with honey and water.

After experiments with bees in the incubator had demonstrated that the brood food glands could be stimulated by pollen substitutes, the next step was to test out the substitute as a food for the larvae during the period of progressive feeding after the second day of life. In order to get a pollen-free area, a colony of bees was put into an enclosed space 30 feet x 10 feet in an insectary. The old bees soon

died off, because they could not adjust themselves to the small range, but the bees which hatched out in the insectary took to it kindly enough.

The queen ceased laying as soon as she was enclosed, but when the young bees started flying they were supplied with pollen substitute in artificial flowers, and a little desultory egg laying began. The bees stored the substitute (casein, yeast, and pollard) in the cells, and apparently reared some brood on it, as capped brood was seen shortly afterwards in one of the combs. The difficulty of being quite certain that no trace of pollen was present in any of the combs from which the young brood emerged added to the fact that the brood cappings eaten by the emerging adults are made up of a mixture containing pollen, make it necessary to repeat the experiment a number of times.

Another hive was made up of capped brood combs and placed in a compartment in the insectary. Sugar syrup was fed outside the hive for two and a half months, and no pollen substitute given, so that if any pollen existed in the hive it would be completely used up. No brood rearing took place during the period. On 20th February, 1932, a frame was filled with pollen substitute and placed in the hive. It was noticed that after the pollen substitute had been put in the hive the bees began to fly more freely than before. However, no brood rearing took place.

On 31st March, a piece of comb containing eggs, unsealed larvae, and a few sealed cells was cut from a comb in an outside hive. All traces of pollen were carefully removed, and the piece of comb fitted into a space in an empty brood comb. This was placed in the experimental hive in the insectary, and abundant dry pollen substitutes shaken into the empty cells surrounding the brood. This substitute was made up as follows:—

Pure casein	..	..	..	25 parts.
Yeast (dried)	..	..	..	1 part.
Pollard	..	..	..	6 parts.
Pea flour	..	..	..	1 part.
Dried milk	..	..	..	1 part.

The hive was then closed up for 16 days and sugar syrup fed to the bees. During these 16 days, all sealed brood would have hatched out, and all larvae which had reached the progressive feeding stage when put into the hive would have pupated and emerged adults. When the hive was opened after the 16 days, eggs and brood in all stages were present, the queen having been stimulated to lay by the presence of the other brood. All the brood present then was either the progeny of the queen of the experimental hive or else from eggs or larvae, under three days old, from the outside hive. All the brood had been reared in the experimental hive from at least the mass feeding stage or the egg stage, and had been fed by bees which had had no protein food except the pollen substitute for their own nutrition and for feeding the older larvae. A piece of comb containing sealed brood was cut out and placed in an incubator. Adults emerged from the 17th day onwards, all apparently healthy. A fresh cell capping removed on the 17th day disclosed a larva which pupated on the 19th day. This larva, which would probably have been from an egg laid about 11 days before, must have been laid by the queen in the experimental hive. The experiment is being continued to check the present indications, but meanwhile it can

be stated that bees have been reared from egg to adult on a pollen substitute.* Further experiments will be necessary as checks, and also to discover if the adults reared on substitutes are as efficient and as resistant to disease as normal adults.

6. Investigations in the Field.

Mr. Beuhne has kept in touch with the investigator on the one hand and with the apiarists on the other. If a pollen shortage occurs, it is hoped that he will be able to help in conducting experiments to try out the pollen substitutes under commercial conditions.

7. Acknowledgments.

The writer is indebted to Dr. R. J. Tillyard for constructive criticism in the preparation of the manuscript, and to Mr. M. R. Freney for information on chemical points in connexion with the research.

* American investigators have succeeded in rearing larvae on pollen substitutes, but none of these larvae, so far as we are aware, were able to pupate and emerge adult.

The Root System of the Sultana.*

By C. Barnard,† M.Sc.

Summary.

The observations, recorded here in respect to the Sultana vine in the Mildura district, have been made primarily for the purpose of supplying information which is required for investigations dealing with methods of cultivation and irrigation. It has been found that—

- (1) The rooting habit of the Sultana is shallow and widespreading, and a considerable overlap of the root systems of adjacent vines planted 11 x 9 feet occurs, restricting the growth of the individuals.
- (2) Sub-soiling prior to planting increases the depth at which the main roots normally develop, though neither subsequent drainage nor irrigation has much effect in this respect. The depth of penetration of the smaller roots, however, is controlled by drainage.
- (3) Root pruning occasioned by winter ploughing to a depth of 9-10 inches is beneficial.
- (4) The feeding roots are annual structures, invariably associated with an endophytic mycorrhiza, and are developed at a depth of 5-10 inches at the base of the cultivation zone.
- (5) The root growth commences about five weeks after the rise of the sap begins and three weeks after bud-burst.
- (6) The great mass of feeding roots present by the end of November are borne on new extension growth, which has arisen from the ascending laterals, decapitated during winter ploughing.

1. Introduction.

The importance of an exact knowledge of the root development of crop plants has become increasingly apparent during the last few years. The practice in the past has been to record the responses of a plant to any treatment by studying the reaction of the aerial portion only. It is now recognized, however, that an understanding of the reactions of the root system, which constitutes one-half of the individual plant, is often of paramount importance in planning experiments and interpreting the results. It is also of importance in determining sound methods of tillage as well as a scientific procedure in the application of irrigation water and fertilizers. Recent horticultural research in Australia into these questions has indicated the need for an investigation of the root development of our orchard trees. Such studies have been commenced, and the results obtained in respect to the sultana grape are presented in this article. The immediate objects of the inquiry were—

- (a) to determine the normal type of permanent root system laid down under irrigation in the Mildura district;
- (b) to investigate the seasonal development of the roots, with special reference to the reaction of the feeding rootlets to the cultural practices and system of periodic irrigation obtaining in that settlement.

* This investigation was carried out at the Commonwealth Research Station, Merbein, Victoria, during the years 1923 and 1929, while Mr. Barnard was an officer of that station.

† Botanist, Division of Plant Industry, C.S.I.R.

2. The Structure of the Root System.

The general structure of the vine root system may be regarded as analogous to that of the aerial portion of the plant, in that a number of main roots, which branch freely, form the framework of the system, and correspond to the branches. These roots are perennial, although growth ceases in winter and recommences in spring, the older portions becoming woody structures similar to the woody branches. On the youngest portions of these permanent roots, small absorbing or feeding rootlets are borne, and these, in a sense, correspond to the leaves. They are of limited growth, hardly ever being more than $1\frac{1}{2}$ inches long, never becoming woody, and functioning for one season only. The root system of the sultana is thus composed of two types of roots, the permanent or extension and the temporary or feeding roots.

The main roots originate from the base of the trunk at a depth of 12 inches to 14 inches, and spread radially, sloping gently downwards. Their extent and degree of ramification depends principally on the age of the vine, though the number of main roots is not increased after the second or third year from planting. In the case of eight-year old vines, they normally attain a length of 9 to 12 feet, and at this distance have reached a depth of 18 to 20 inches.

The smaller permanent roots arising from the main root system show a marked tendency to rise towards the surface of the soil, though a few are developed below the level of the main roots between 18 inches and 30 inches, and occasionally "plunging" roots of this order penetrate to a depth of 4 feet.

The feeding roots are, for the most part, borne on the ascending laterals, and form a zone 5 inches to 10 inches below the surface of the soil, but they may rise even closer to the surface when not displaced by cultural operations.

3. Permanent Roots.

(a) *Horizontal Distribution.*—The framework, as stated above, spreads in a horizontal plane in all directions, the main roots averaging approximately 10 feet. Some, however, reach 15 or 16 feet, and an occasional one may attain a length of 24 feet. As the vines are planted 9 feet apart in rows 11 feet apart, the roots overlap considerably, and the growth of each is reduced by competition. The effect of this overlap has been shown by means of a comparison between the end vine of the row and the third one. The circumference of the butt at a level of 6 inches above the ground and the amount of annual wood removed at pruning were taken as a measure of vegetative development. The figures obtained in this study were as follows:—

			No. of Vines.	Mean Circumference of Trunk.	Difference.	Standard Error of Difference.	Probability.
Terminal vine	..	..	19	22.5 cm.	2.4 cm.	.65 cm.	.0001
Third vine	..	..	19	20.1 cm.	..	..	..
				Wt. of Prunings.			
Terminal vine	..	..	19	5.5 lb.			
Third vine	..	..	19	4.3 lb.	1.2 lb.	.31 lb.	.00005

The greater vigour of the terminal vine is obviously due to the fact that the root system meets with no competition on one side.

A similar examination on a field in which the end vine had been planted at an average distance of 6 ft. 3 in. from the second vine, whilst the second was placed at the standard 9 feet from the third, gave results just as conclusive in the reverse direction. Eleven pairs showed that the mean circumference of the terminal vines was 17.1 cm., and that of the third vines 20.7 cm. The mean difference is 3.6 cm. The third vine is normal in size, and comparable to the third vine on other fields, but the closer spacing between the terminal and second vines had been more than sufficient to counter-balance the usual advantage enjoyed by the terminal plant.

Deep ploughing operations at the end of winter actually help to decrease this overlap, as the main roots are often cut. This results in the formation of strong new growth in spring within the area allotted to each vine, and is undoubtedly a beneficial practice. The laterals ascending from the main roots are also cut severely by the deep ploughing. New extension growth, however, arises from the cut ends, and, growing horizontally, forms a mass of new roots at the base of the cultivation zone. Bunches of feeding rootlets arise from these new roots during the same growing season, while cultivation to a depth of approximately 5 inches prevents the feeding zone from rising nearer to the surface of the soil.

(b) *Vertical Distribution.*—The vertical distribution of the roots is correlated with the soil profile in which three distinct horizons are found in the first 3 feet of soil. These are described below—

(i) The cultivated zone, which is divided into an upper tilth layer of approximately 5 inches and a lower layer representing the soil, which is disturbed only by deep ploughing. This second layer extends from 5 inches down to about 9 inches, and by reason of its slightly darker colour, is sharply defined from the horizon beneath.

(ii) A zone extending from 9 inches to a depth of approximately 16 inches, composed of the same soil as horizon (i) and differing mainly in possessing a much lower humus content.

(iii) Between 16 inches and 18 inches, horizons (ii) and (iii) merge into one another. Horizon (iii) is slightly heavier in texture than the overlying soil, and is generally characterized by the presence of leached nodules of lime, which give it a mottled or blotched appearance. This horizon extends to a varying depth, and becomes heavier below 36 inches.

The distribution of the roots in relation to the soil profile is illustrated in Figure 1. The main scaffolding roots lie at the junction of horizons (ii) and (iii), whilst the tendency of the smaller roots which arise from them is to ascend through horizon (ii) to the basal layer of horizon (i), where they bear large masses of feeding rootlets along their ultimate branches. The depth and extent of each of the three horizons varies throughout the district, and this variation is more important than any differences in the texture of the soil in determining the vertical distribution of the roots.

The distribution of the main roots is not modified by drainage subsequent to planting or by irrigation, but is markedly influenced

by the treatment of the soil prior to planting. Deep sub-soiling of the land before planting undoubtedly results in more deeply-seated main roots.

The small roots, however, respond to the influences of irrigation and drainage, the former limiting and the latter inducing deep penetration. Even moderate irrigation without sufficient drainage may limit the depth of penetration to within 24 inches of the surface. Natural or artificial drainage on the other hand induces the development of small roots in the sub-soil. In the case of natural drainage, the open texture of the sub-soil results in their more or less uniform distribution down to a depth of 3 feet, whilst in the case of artificially-drained land, though a general downward trend is manifest, it is only in the immediate vicinity of the drains that many roots occur at this depth.

It may safely be stated that the tendency for the majority of laterals to ascend towards the surface and the occurrence of a definite horizon of feeding rootlets at the base of the cultivation zone is not a feature induced by irrigation, the habit of surface feeding being natural to the vine.

4. Annual Growth.

The feeding roots of the sultana are sharply differentiated from the permanent or extension roots. They are of limited growth, and do not form any secondary tissues. They attain a length of $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches, and rarely branch. For the most part they occur on the current season's growth of the extension roots, and a new crop is produced annually. This type of feeding-root is quite different from the fibre type found in most orchard trees.

The ascent of the sap about the middle of August indicates the commencement of root activity, though new root growth does not appear until the third week in September. During this period, the only feeding roots present are a few of the last season's, the majority of which are decayed, brownish or black in colour, and devoid of any functional root hairs (1, Figure 2). In view of this fact, it is most remarkable that the flow of sap before the appearance of the new growth has been sufficient to bring about bud burst and initiate the early growth of the shoots.

The mechanism by means of which the vine is able to absorb moisture so rapidly during this period is not understood at present, but it seems probable that the endophytic mycorrhiza which is mentioned below, may play an important role in this connexion.

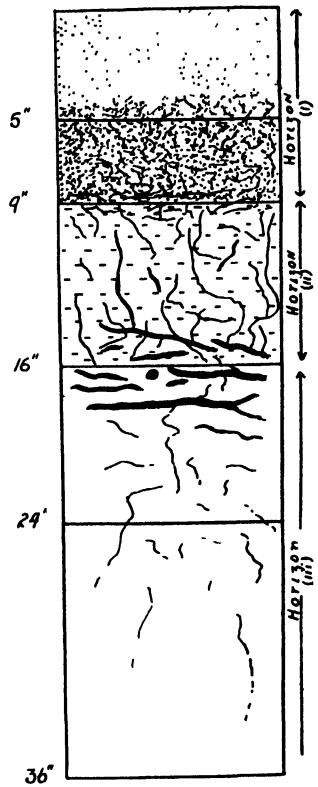


FIG. 1.—The soil profile and the vertical distribution of the roots.

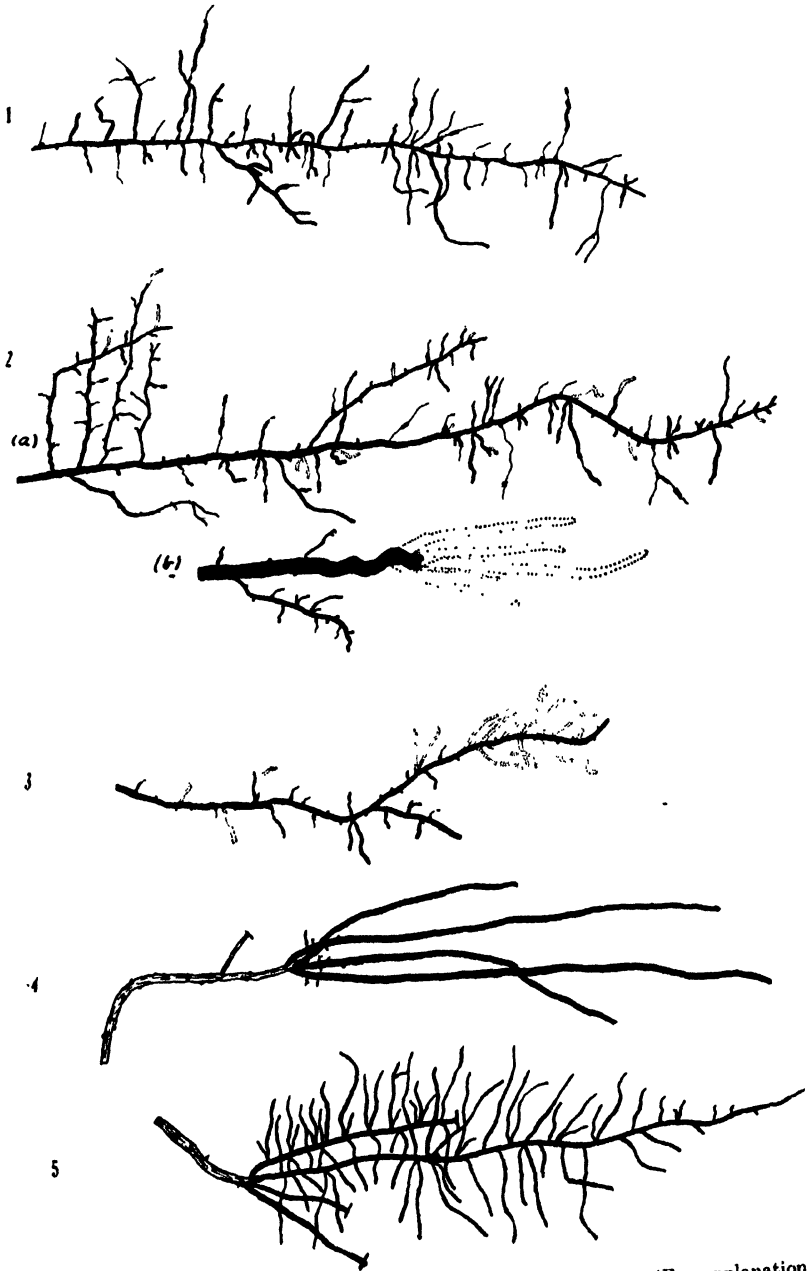


FIG. 2.—Growth during the season; about half natural size. (For explanation see text.)

Such a late development of new root growth has also been recorded in France,* but is contrary to the common belief that the bleeding of the vine is caused by the absorption of water by newly-formed roots.†

The first new growth consists of a few feeders arising on the previous season's elongation growth (2 (a), Figure 2) and extensions of the permanent roots (2 (b), Figure 2). The most marked development of the latter occurs near the surface of the soil, and originates from the ascending laterals, which have been decapitated during the winter ploughing operations. Two to six strong new extensions arise from the cut ends of such roots. The development of the new feeding rootlets is comparatively slow during October, and the stage reached towards the end of the month is illustrated in 3, Figure 2. About this time, new feeders appear at the base of the new elongation growth, which is shown in solid black in 4, Figure 2. The development of new extension root growth then becomes very rapid. By the third week in November these roots have reached lengths of 7 inches and 8 inches, and are covered with large numbers of feeder roots 5, Figure 2.

The young rootlets produce root hairs fairly abundantly early in the season, but by the end of November most of the feeders are mature, and there are very few rootlets with functional root hairs.

The effect of irrigation depends on the time of application, thus—

(a) Watering at the end of November results in the formation of white tips on the extension of growth and on some feeding rootlets, as well as in the formation of a few feeding rootlets on older roots. The average extension arising as a direct result of this irrigation was about 2 inches. The new growth soon turned brown, and growth apparently slowed down again approximately three weeks after the application of water.

(b) Watering at the beginning of January has the same effects, but the extensions to the permanent roots average only 1 inch. Later irrigations have a less marked and more temporary effect.

An endophytic mycorrhiza is invariably associated with the mature rootlets and a preliminary study of its development through the season has been made. It would appear that though at first the fungus is parasitic, the rootlets quickly react to its presence, and digestion of the hyphae to a certain extent takes place. The role played by the mycorrhiza in the nutrition of the vine is a subject, however, which requires further investigation.

5. Acknowledgments.

The author wishes to thank Dr. B. T. Dickson, Chief of the Division of Plant Industry, C.S.I.R., and Professor T. G. B. Osborn, of the University of Sydney, for helpful advice during the course of these studies. He is also indebted to Mr. A. V. Lyon, M.Sc.Agr., Officer-in-Charge, Commonwealth Research Station, Merbein, for assistance during the investigations.

* L. Rives—*Recherches sur Quelques Formes de Deperissements de la Vigne, Court nous etc.* Toulouse, 1926.

† A. I. Perolt—"A Treatise of Viticulture," MacMillan & Co., London, 1927.

The Chemical Treatment of Baits for Attracting Blowflies. I.

By Martin R. Freney,* B.Sc.

(Published on the recommendation of the Joint Blowfly Committee.†)

In submitting the following paper by Mr. Freney for publication, the Joint Blowfly Committee realizes that in ordinary circumstances it would have been preferable to await the results of further experimental work. The present strike season for Canberra is practically at an end, however, and several months must elapse before similar experiments can be conducted there. In the warmer districts, nevertheless, it will be possible for pastoralists to test the new baits on a large scale, and information regarding the results observed will be greatly appreciated. Although the pure form of sodium sulphide was used by Mr. Freney for obvious reasons, in all probability the commercial product, which is comparatively cheap, will prove equally satisfactory.

Not only will pastoralists who are endeavouring to cope with the blowfly pest by means of trapping be greatly interested in these experiments, but investigators of the problem as it occurs in other parts of the world will be equally interested. In Europe and North America, the latter will have opportunities of continuing or initiating experiments along similar lines during their strike season which is now approaching.

For these reasons publication is considered advisable at the present juncture.

J. A. GILRUTH,

Chairman of Joint Blowfly Committee.

In an earlier paper (this *Journal* 5:28, 1932), it was shown that a mixture attractive to primary blowflies could be obtained by hydrolysing keratin by means of sodium sulphide. This work has now been extended to include other substances which are rich in protein. Among these have been fresh sheep's liver and "blowfly soup," two of the baits most commonly used by pastoralists in blowfly traps. The present paper deals with the results obtained by treating these two baits with sodium sulphide.

Experiment 1.

Set up 8th February, terminated 4th March, 1932. Two small traps designed by Dr. A. J. Nicholson for use in experimental work were used.

Trap A was baited with 50 grams of fresh sheep's liver, to which 20 c.c.s. of water was added.

Trap B was also baited with 50 grams of fresh sheep's liver and 20 c.c.s. of water in which 5 grams of hydrated crystalline sodium sulphide was dissolved, i.e., a 20 per cent. solution.

Each day flies were removed from the bait-pan of both traps, and water was added to replace that lost by evaporation. The flies caught were killed, counted, and classified daily.

Trap A caught significant numbers of flies on the 1st to the 4th, and on the 7th to the 10th days of exposure. From the 10th to the 25th day, fourteen flies were caught. Numerous maggots developed in this bait, and by the 9th day the solid bait had become almost completely liquefied. The catches obtained in Trap B showed some fluctuations, but maintained a fairly steady average rate right to the end of the experiment. Very few maggots matured in this bait.

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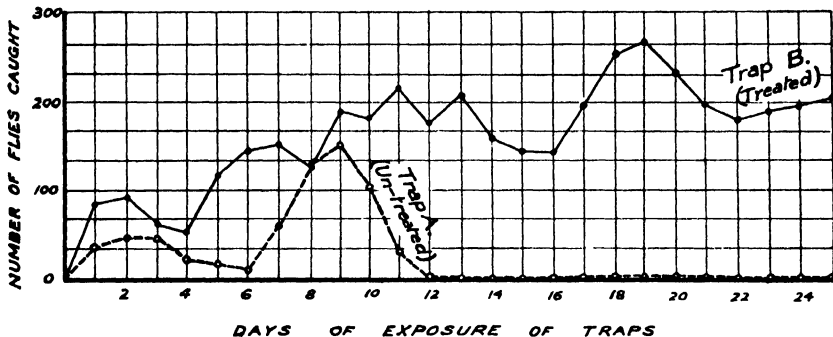
† Composed of representatives of the Council and of the New South Wales Department of Agriculture. (See this *Journal*, February, 1932, page 28)

The results of the experiment are shown in the following table and graph:—

TABLE 1.

	Number of Flies. First 9 days' exposure.				Number of Flies. Total 25 days' exposure.			
	Trap A. Untreated.		Trap B. Treated.		Trap A. Untreated.		Trap B. Treated.	
Primary Flies—	females.	males.	females.	males.	females.	males.	females.	males.
<i>L. cuprina</i> ..	20	3	17	18	20	3	60	45
<i>L. sericata</i> ..	1	..	3	1	1	..	9	6
<i>C. stygia</i> ..	18	..	18	..	18	..	37	4
<i>C. augur</i> ..	459	19	918	31	460	19	2,358	186
Secondary Flies—								
<i>Ch. rufifacies</i> ..	61	5	265	18	64	5	683	184
<i>M. varipes</i> ..	53	..	30	..	55	..	343	..
<i>Sarcophaga</i> spp. ..	8	..	22	..	16	..	93	..
Primary Green Flies ..	24	3.7%	39	2.9%	24	3.6%	120	3.0%
Primary Brown Flies ..	496	76.7%	967	72.1%	497	75.2%	2,585	64.5%
Secondary Flies ..	127	19.6%	335	25.0%	140	21.2%	1,303	32.5%
Total ..	647	100%	1,341	100%	661	100%	4,008	100%

NOTE.—Primary Green Flies are *Lucilia cuprina* and *Lucilia sericata*. Primary Brown Flies are *Calliphora stygia* and *Calliphora augur*. Secondary Flies are *Chrysomyia rufifacies*, *Microcalliphora varipes* and *Sarcophaga* spp.



Graph 1. Daily catch of blowflies. Broken line Trap A (untreated bait); continuous line Trap B (treated bait). The points have been determined by a three point method of moving averages to show clearly the general trend of the catches.

This experiment showed that—

- (i) the period of attractiveness of the sulphide-treated bait was much longer than that of the untreated bait;
- (ii) the sulphide-treated bait was more attractive to all species of blowflies than the untreated bait; and
- (iii) the increased attractiveness due to treatment was somewhat greater for secondary flies than for primary flies.

A similar experiment using Western Australian traps and larger baits was set up on the 4th March. Cold and rainy weather interfered considerably with this experiment, and the results were not conclusive, but again the treated traps caught a larger number of flies and remained attractive for a longer period than the untreated traps.

Experiment 2.

Set up 29th February, terminated 24th March. "Blowfly soup" was prepared by allowing trapped blowflies to putrefy in water in a Meteor trap for five days. The soup was stirred and divided into two

portions, each of three litres. Standard Western Australian traps* were baited with these, and to one was added 50 grams of crystalline sodium sulphide. Water was added from time to time to make up for that lost by evaporation. Despite unfavorable weather during the latter part of the experiment, the results were well defined and are shown in Table 2. For comparison, the analysis of a week's catch in Miss Fuller's seasonal record Western Australian trap (which is baited with 1,000 grams of fresh liver) is shown in the first column.

TABLE 2.

—	Fresh Liver.		Blowfly Soup.							
	1st March to 8th March, 1932.		8 days—29th February to 8th March, 1932.				24 days—20th February to 24th March, 1932.			
	Control.		Untreated.		Treated.		Untreated.		Treated.	
Primary Flies—			females.	males.	females.	males.	females.	males.	females.	males.
<i>L. cuprina</i> ..	50		4	6	80	..	4	6	85	..
<i>L. sericata</i> ..	45		2	..	20	15	2	..	40	15
<i>C. stygia</i> ..	450		61	29	520	125	62	29	1,090	140
<i>C. augur</i> ..	5,200		1,046	87	4,460	590	1,050	89	6,060	830
Secondary Flies—										
<i>Ch. rufifacies</i> ..	5,500		61	45	10,800	4,170	64	46	12,110	4,590
<i>M. varipes</i> ..	4,350			140		9,800		148		11,400
<i>Sarcophaga</i> spp.	150			324		530		444		810
Primary Green Flies ..	95	0.6%	12	0.6%	125	0.5%	12	0.6%	140	0.4%
Primary Brown Flies ..	5,650	36.0%	1,223	67.5%	5,695	18.4%	1,234	63.2%	8,120	21.8%
Secondary Flies ..	10,000	63.4%	570	31.9%	25,300	81.1%	706	36.2%	29,000	77.8%
Total ..	15,745	100%	1,805	100%	31,120	100%	1,952	100%	37,210	100%

This experiment showed that—

- (i) the period of effective attractiveness of the sulphide-treated bait was much longer than that of the untreated bait, the former catching 15,000 flies and the latter 300 flies between the 4th and 24th days of the experiment;
- (ii) the untreated bait was much less attractive than either fresh liver or the treated blowfly soup;
- (iii) the treated bait was as attractive for primary flies, and more than twice as attractive for secondary flies as the fresh liver during the first eight-day period;
- (iv) the total effectiveness of the treated bait was nineteen times that of the untreated bait; and
- (v) treatment increased the attractiveness of the bait for all blowflies, but more for secondaries than for primaries.

Discussion.

Although the work is in an early stage, two important facts have been demonstrated and are worth recording. In the first place, it has been shown that the attractiveness of the bait to all species of blowflies can be increased by the sulphide treatment. This applies to the period in which the untreated bait is also attractive, i.e., to the first eight to ten days of exposure under the weather conditions prevailing at the time of the experiments. Thus, during this period, the ratio of the blowflies

* Meteor traps are not satisfactory for this work because the flies attracted cannot be counted or classified accurately.

caught by the treated bait to those caught by the untreated bait was 2:1 in Experiment 1 and 16:1 in Experiment 2. Most remarkable was the increase in the attractiveness of the blowfly soup. This bait has many advantages for practical use, but it has been shown in this laboratory that its attractiveness is distinctly lower than that of fresh liver. It now appears probable that this fault can be overcome by chemical treatment.

The increase in attractiveness is in general greater for secondary flies than for primary flies. This may be a disadvantage, but it is not proposed here to discuss its significance. Certain observations, however, suggest that this may be overcome by further treatment of the bait.

The second effect of the sulphide treatment is to prolong the period of attractiveness of the bait. This effect was more marked in Experiment 1 than in later work, and some observations made by Dr. Nicholson suggest that this prolongation is likely to be more pronounced in hot weather than in cold. How far it is due to direct chemical effects on the bait and how far to the deleterious effect on the sulphide on the maggots, which would otherwise devour the bait, has not been determined. The significance of this observation is that it opens up the possibility of less frequent baiting of traps than is at present practicable, a matter of considerable importance to those graziers who use blowfly traps.

The combined result of the increased attractiveness and the lengthened period of attractiveness is greatly to increase the efficacy of traps in which treated baits are used. Thus, the ratio of flies caught with the treated bait to those caught with the untreated bait over the whole period of the experiments was:—Experiment 1, primaries 5:1, all blowflies 6:1; Experiment 2, primaries 6.6:1, all blowflies 19:1. These results are in striking contrast with those obtained by Laake, Parman, Bishopp, and Roark* using potassium sulphide. These authors, however, do not give sufficient information to enable their results to be criticized.

In these experiments, certain arbitrary strengths of the hydrated crystalline sodium sulphide, which contains approximately 30 per cent. of the anhydrous sulphide, were used. Further observations are being made on the effect of the fused sulphide, which is both cheaper and stronger than the crystalline form. So far, these have indicated that high concentrations are not satisfactory.

To summarize, progress may be reported in the improvement of baits by chemical treatment, but further work is required at a favorable time of the year to determine—

- (i) the correct amount of sodium sulphide to use under different conditions;
- (ii) whether other chemical substances will produce a similar effect;
- (iii) the effective duration of attractiveness of treated baits in warm weather; and
- (iv) whether the attractiveness of the treated baits for primary flies can be increased.

The author is indebted to Miss M. Fuller and to Dr. A. J. Nicholson for permission to discuss unpublished work, and to Dr. I. M. Mackerras for help and advice in interpreting the results.

Caseous Lymphadenitis :

Ingestion as a Method of Infection of Sheep with the Preisz-Nocard Bacillus.

By *H. R. Carne*,* *B.V.Sc.*

(*From the Pathology Department, F. D. McMaster Animal Health Laboratory.*)

1. Introduction.

Although in Australia caseous lymphadenitis is generally believed to be contracted by sheep as a result of the entrance of Preisz-Nocard bacilli through wounds of the skin, certain of the earlier investigators of this disease were of the opinion that infection was most commonly due to the ingestion of food material contaminated with the causal bacillus. Carré and Bigoteau (1908) investigated a disease of sheep in France which in their opinion was due to an infection by the Preisz-Nocard bacillus, with subsequent toxaemia due to the production of toxin by these bacilli, which were restricted to limited foci of infection in lymphatic glands. Small purulent foci were found in the pharyngeal and retropharyngeal lymphatic glands in natural cases of the disease, and in these foci, pure infections of the Preisz-Nocard bacillus were demonstrated. These investigators considered that the usual portal of entry of the causal microbe is the alimentary canal, by way of slight injuries to the buccal mucosa, the organism being carried to the nearest lymphatic gland and there producing its lesions. A condition comparable with this acute intoxication by the Preisz-Nocard bacillus has never been reported in Australia, and abattoir statistics have shown that infection of lymph glands draining any part of the alimentary canal is rare. Gilruth (1902), who made extensive investigations of the occurrence of this disease in New Zealand, stated that pharyngeal, parotid, or sublingual lymphatic glands were never seen affected.

Cramp (1929) has recently made detailed post-mortem examinations of 2,378 sheep. Submaxillary lymphatic glands were found affected in only two cases, and pharyngeals in one. Extensive unpublished observations by the Meat Export Branch of the Commonwealth Department of Markets† have provided ample confirmation of the rarity of primary lesions associated with the alimentary canal.

A number of experiments in which sheep and also small experimental animals have been drenched with either caseous material from natural lesions, or with cultures of the Preisz-Nocard bacillus, have been reported.

Norgaard and Mohler (1899) gave to sheep food mixed with caseous material from natural lesions. No lesions were found on slaughter 49 days later. Seddon (1929) drenched three sheep with culture, and two with pus. Of those which received culture, two developed lesions in submaxillary, retropharyngeal, mediastinal, and prescapular lymphatic glands (after 60 days), and one of those which received pus developed lesions in submaxillary and retropharyngeal glands. The three sheep

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† Now Department of Commerce.

that became affected all showed lesions in the lymph glands of the head, and it appeared that the lesions present in other parts of the body were secondary to these. No lesions were present in the abdomen or thorax.

Carne and Clunies Ross (1931) drenched seven young sheep with massive doses of culture on two, and in some cases three, occasions. When killed from 37 to 51 days after drenching, three were found to have young lesions of caseous lymphadenitis in the submaxillary lymphatic glands.

So common is this disease in sheep that all infection experiments with sheep are open to the serious criticism that one has no definite proof that lesions found on post-mortem examination did not exist prior to the experiment. If care is taken, however, to use only young animals from flocks in which it is known that incidence of the disease is very low, significance can be placed upon the finding of lesions, particularly if these are examined histologically, as it is possible in this way to distinguish a young from an old lesion. This can be done with considerable accuracy even by the naked eye.

Although the behaviour of one species of animal cannot be presumed from that experimentally demonstrated in another species, the use of guinea-pigs for drenching experiments with the Preisz-Nocard bacillus has the advantages that this micro-organism produces a similar, though more severe, disease to that which occurs in the sheep, and, further the guinea-pig, while being quite susceptible to experimental infection by various routes, is not found naturally affected with the disease, as is the sheep. Drenching experiments can therefore be carried out under much more satisfactory conditions.

Norgaard and Mohler (1899) fed guinea-pigs with diets contaminated with culture. Death took place in five to eight weeks with lesions in the lymph glands draining the mouth and throat, and also later in other parts of the body. (Rabbits developed similar lesions after feeding culture with food, and Gilruth (1902) reported a positive infection by way of the alimentary canal in a rabbit). Recently, Dickinson and Bull (1931) have reported the results of drenching 99 guinea-pigs with culture. Of these, 59 animals became affected. Approximately half of the affected animals showed involvement of the cervical or submaxillary lymphatic glands. The distribution of lesions in some of the animals was of particular interest. In three animals, involvement was confined to the superficial lymph glands. Mediastinal lymphatic glands were only affected in three animals. From this experiment it is clear that, in some guinea-pigs at least, involvement of the superficial lymphatic glands may occur without infection being introduced through external injuries of the tissues drained by these glands.

We have been struck by the fact that, in both sheep and guinea-pigs, which have become infected as the result of drenching, lesions of the alimentary canal and its associated lymph glands, i.e., caudal to the pharynx, are rare. In sheep, when infection occurs as the result of drenching or feeding, the experimental evidence indicates that the portal of infection is the mucous membrane of the mouth or pharynx, and quite a large proportion of guinea-pigs show lesions of the lymph glands draining these cavities. In the buccal cavity, injuries to the mucous membrane may be caused by eruption of teeth, scratches by rough forage, &c., and such injuries act as portals of entry for the

causal bacilli in the same way as do injuries to the skin. It appears that, provided the Preisz-Nocard bacillus gains entrance to the buccal cavity, infection may take place via the buccal mucosa.

It is known that the lower part of the alimentary canal—stomach, small and large intestines—are by no means exempt from traumatic injury in the sheep, particularly by parasitic worms which are so constantly present, and frequently in large numbers. It would appear, therefore, that injuries of the gastric and intestinal mucosae are not lacking, and thus potential portals of entry for the Preisz-Nocard bacillus are numerous, yet in contrast with the findings in the buccal cavity, both naturally infected animals and animals which have been experimentally drenched, fail to show lesions of the lymph glands draining this part of the alimentary canal. We have shown (Carne and Clunies Ross, 1931) that even though widespread injury to the large and small intestine is produced by experimental infestation with large numbers of *Oesophagostomum columbianum*, and then massive repeated doses of culture of Preisz-Nocard bacilli are administered by drenching, thus providing a far greater concentration of the infective agent in the ingesta than could ever occur under natural conditions, yet even then lesions of caseous lymphadenitis of the stomach and intestines or their associated lymphatic glands did not occur except in one doubtful case, which may have been a secondary lesion.

As the result of these observations, we have been led to consider the possibility of the gastric secretion having a destructive action on the Preisz-Nocard bacillus which reaches the abomasum. On the supposition that the gastric juice might possess such an injurious effect, the following experiments were carried out to ascertain the result of introducing cultures of this organism per rectum.

2. Ingestion Experiments with Sheep.

Experiment 1.—A sheep was starved overnight, and the next morning given a purgative drench of magnesium sulphate. The animal was then starved, but allowed water for 24 hours, in order to allow the alimentary canal to be emptied as completely as possible. The rectum was finally washed out with copious enemas of water. By means of a sling around the loins, the hind-quarters of the animal were raised well above the level of the head, so that any fluid introduced per rectum would gravitate forward in the intestine. A rubber tube was then passed 3 feet along the colon, and through it was administered the combined cultures of Preisz-Nocard bacilli from seven agar slopes. The animal was kept in this position for twenty minutes, and then set free. This procedure was repeated in three days' time. Three weeks later, this sheep was killed, and no lesions of caseous lymphadenitis could be found throughout the body.

Experiment 2.—This was a repetition of Exp. 1, only in this case the sheep was not killed till six weeks after culture was administered, and *post-mortem* examination included culturing material from the lymphatic glands draining the intestines. No lesions of caseous lymphadenitis were detected, and cultural examination of lymph glands was negative.

The following experiments were designed to ascertain whether the filtered gastric juice of the sheep had any demonstrable injurious effect on the Preisz-Nocard bacillus.

Experiment 3.—The abomasal contents of four sheep were collected in clean bottles immediately the animals were opened up after slaughtering. Bottles were then packed in freezing mixture, and brought straight to the laboratory. This occupied approximately half an hour. Each sample was then filtered through paper, and finally filtered through either a Seitz EK special filter pad, or a Chamberland L3 candle. Some of each filtrate was then sown on serum broth to test for sterility. (All proved subsequently to be sterile). Of each remaining filtrate, 5.0 ccs. was introduced into a sterile test-tube, and placed in the incubator at 37° C. in order to bring it to blood heat. To each was then added two standard loopfuls of a 48-hour serum broth culture of Preisz-Nocard bacilli, which had been rendered as free from clumps as possible. Tubes were then agitated and replaced in the incubator. Subsequently, two standard loopfuls were removed and spread over the surface of serum agar plates at the end of the following periods after initial introduction of culture:—10 minutes, 25 minutes, 50 minutes, 1 hour 15 minutes, 1 hour 25 minutes, 1 hour 35 minutes, 1 hour 45 minutes, 2 hours, and 2½ hours. It was not considered necessary to continue observations over longer periods, as 2½ hours is about the maximum period that food would stay in the abomasum.

A control series of plates was run to each sample of gastric juice, consisting of a similar quantity of saline, into which were introduced two standard loopfuls of culture.

The results are shown in Table 1.

TABLE 1.

Time in Minutes	Sample A.		Sample B.		Sample C.		Sample D.	
	Gastric Juice. Approx. No. of Colonies.	Saline Control. Approx. No. of Colonies.	Gastric Juice. Approx. No. of Colonies.	Saline Control. Approx. No. of Colonies.	Gastric Juice. Approx. No. of Colonies.	Saline Control. Approx. No. of Colonies.	Gastric Juice. Approx. No. of Colonies.	Saline Control. Approx. No. of Colonies.
10	500	400	500	500	400	20*	400	200
25	500	500	150	400	400	400	500	300
50	500	500	150	500	150	100*	500	500
75	150	500	50	500	30	500	500	500
85	500	500	50	500	8	400	500	500
95	500	500	22	300	12	400	500	400
105	500	500	17	500	2	500	500	500
120	500	500	5	500	5	400	500	500
150	500	400	2	400	0	400	500	500

* Plates badly spread, resulting in confluent colonies, which could not be accurately counted or estimated.

This experiment showed in samples B and C a definite decrease in the number of colonies on the plates sown with organisms which had been exposed to the action of gastric juice as compared with those which had been in saline under the same conditions. No significant difference occurred between samples A and D and their respective controls.

A second experiment of the same design was carried out, using a large collective sample of gastric juice from over 20 sheep instead of separate samples from individual sheep. The results of this experiment, however, showed no significant difference between the number of colonies

which developed on test and control plates. Because of our inability to confirm the suggestive results obtained in Exp. 3, the results of this experiment must be regarded with reserve.

The experimental observations available show quite definitely that sheep can be infected by ingestion or drenching of Preisz-Nocard bacilli. Such experimental administration of virulent organisms leads in most cases to infection of the lymphatic glands draining the buccal cavity, infection of the more caudal portions of the alimentary canal being rare. Since post-mortem evidence at the abattoirs shows that infections of lymphatic glands both of the gastro-intestinal tract and of the buccal cavity are very exceptional in sheep becoming infected under natural conditions, this would indicate that infection by ingestion, though possible, is not a common method of infection in sheep under natural conditions.

The experimental evidence suggests that Preisz-Nocard bacilli which reach the lumen of the intestine either by traversing the abomasum or by introduction per rectum, do not find suitable conditions there for penetrating into the tissues of the host to produce their characteristic lesions.

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Caseous Lymphadenitis: The Growth of the Preisz-Nocard Bacillus in Sheep Faeces.

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1. Introduction.

The natural method or methods by which sheep contract infection by the Preisz-Nocard bacillus has naturally attracted special attention in the investigation of caseous lymphadenitis. Extensive detailed post-mortem observations on the distribution of the lesions of this disease have been made by veterinary officers of the Meat Export Branch of the Commonwealth Department of Markets, and by members of the veterinary staffs of the State Abattoirs (e.g., R. C. Cramp (1929).*) These observations have emphasized the fact that the great majority of lesions are found in lymphatic glands draining the superficial parts of the body, whereas primary lesions of the alimentary canal are rare. Lesions are sometimes found in internal organs, not uncommonly in the lungs, and less frequently in the liver, kidneys and spleen, but such visceral lesions are metastatic infections, resulting from transportation of the causal bacilli by the lymph stream from affected superficial lymphatic glands to the lungs, and from there extensions may occur by organisms escaping into the general circulation, leading to their eventual arrest in various visceral organs, which appear to be predilection seats for the bacilli.

The preponderance of lesions in superficial lymphatic glands, together with clinical evidence collected in the field, strongly supports the view that the common natural method of infection is by the causal bacillus gaining entrance to the superficial parts of the body via wounds of the skin. The rarity of primary lesions of the alimentary canal suggests that infection via the alimentary canal is at least not a common natural method. The fact that primary lesions of the alimentary canal are not observed, however, does not exclude the possibility of infection taking place by this route. Experiments with the causal bacillus of glanders of horses have shown that at times when organisms were administered in sterile boluses from which the glanders bacilli were not liberated until disintegration had resulted from the action of gastric juice, primary lesions were observed in the lungs, and no evidence of any injury to the alimentary canal could be detected, the glanders bacilli apparently being able to penetrate through the bowel wall, possibly enclosed within phagocytic cells, without injury to the alimentary canal.

Carré and Bigoteau,† working in France, have expressed the opinion that ingestion of contaminated foodstuffs is a common method of infection. This opinion appeared to be based largely on the observation that the Preisz-Nocard bacillus was able to multiply readily in sterilized sheep faeces. Although the evidence provided by the post-mortem observations on the distribution of lesions in naturally infected animals, and the negative results following drenching of cultures to sheep, have been

* New South Wales Department of Agriculture, Veterinary Research, Report No. 4, p. 32 (1929).

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† *Rev. gén. de méd. vét.*, 17: 433, 1908.

recorded by several investigators, Dickinson and Bull† have recently shown that drenching guinea-pigs with cultures of the Priesz-Nocard bacillus may apparently be followed at times by the development of lesions of the superficial lymphatic glands, without any observable lesions in the alimentary canal, or the lymph glands which drain it.

2. The Growth of the Preisz-Nocard Bacillus in Sheep Faeces.

If the Preisz-Nocard bacillus were able to grow in sheep faeces, as claimed by Carré, it appeared that such an abundant medium would serve as an excellent means of propagation of the organism outside the animal body, as it will grow quite readily at ordinary room temperatures on artificial culture media. Furthermore, if this organism were able to grow readily in sheep faeces outside the animal body, it might also be able to grow even more readily in the contents of the alimentary canal. If such a state of affairs existed, the numerous injuries to the mucous membrane of the bowel wall, caused by the worm parasites to which the sheep is susceptible, and with which it is so commonly infested, would provide the necessary portals of entry for the organisms into the tissues.

Confirmation of Carré's observation was therefore sought by carrying out the following experiments:—

A. Sterilized Sheep Faeces.

Experiment 1.—A sample of sheep faeces was collected at random from the experimental sheep pens. This was rubbed up in a mortar with tap water till of a soupy consistence. This liquid was then tubed and autoclaved at 120° C. It was found that a loopful of broth culture of the Preisz-Nocard bacillus seeded into this culture medium and incubated at 37° C. grew readily, so that after 48 hours incubation, examination of a loopful of culture revealed several thousand bacilli in each microscopic field. The point was not satisfactorily settled by this simple initial experiment, however. On mentioning this favourable result to two of our colleagues, we were surprised that they had carried out similar experiments without obtaining growth. On repeating the experiment ourselves, we found on this second occasion no evidence of multiplication of the organisms used for seeding, though these had still remained alive.

The following experiment threw some light on these negative results:—

Experiment 2.—Three lots of sheep, (a), (b) and (c), containing six, four, and six animals respectively, were fed on the following diets for a period of one week:—

- (a) Green field peas.
- (b) Oaten chaff and bran.
- (c) Green grass growing around the Laboratory (composed of couch (*Cynodon dactylon*), 60 per cent., clovers and medics, 20 per cent.; *Poa annua*, 15 per cent.; *Paspalum dilatatum* and *Taraxacum densleonis* together constituting 5 per cent.).

At the end of this period, a collective sample of faeces was taken from each lot. The hydrogen-ion concentration of each collective sample was determined and found to be as follows:--

(a) $pH = 6.6$.

(b) $pH = 6.5$.

(c) $pH = 7.3$.

A portion of each sample was then rubbed up with sufficient distilled water to reduce it to the consistence of thick porridge. This was poured in layers about 1.0 cm. deep in Petri dishes, which were then sterilized by autoclaving at 120° C. for 30 minutes, and subsequently found to be sterile.

Petri dishes prepared from each sample were then inoculated with a 1:10 dilution in physiological saline of a broth culture of Preisz-Nocard bacilli, which had been rapidly centrifuged for several minutes to throw down the larger clumps. A small depression was made in the centre of each dish by pressing down the medium with the end of a sterile glass rod. Into these depressions was placed one loopful of the diluted culture. By cultural tests of serial dilutions on serum agar plates, it was ascertained that this loopful of seeding material contained at least 42,000 organisms. The Petri dishes were then incubated at 37° C. After seven days, distinct small greyish colonies were seen to develop around the site of inoculation in several dishes containing faeces from animals fed on green peas. These proved to be pure colonies of Preisz-Nocard bacilli.

A loopful of faeces was taken from each plate at three points approximately 2.5 cms. from the site of inoculation, and also three more loopfuls from the margin of the plate, and all were sown into tubes of serum broth. In two of the dishes containing faeces from sheep fed on green field peas, a pure culture of Preisz-Nocard bacilli was obtained from material taken from points 2.5 cms. from the site of inoculation, and also from the margin of the culture (dishes were 9 cms. in diameter). Smears made from the faeces at the edge of the plates in these dishes showed approximately 200 organisms per microscope field.

In all plates except those containing faeces from sheep fed on green field peas, no evidence of growth was obtained, either by cultural methods or by direct microscopical examination of the faecal culture medium itself in smears.

This experiment indicated that the nature of the foodstuff on which the sheep has been nourished may play an important part in determining whether the sterile faeces will be a suitable culture medium for the organism. It should be noted that the amount of liquid used as seeding material was too small to account for spread of the organisms to the edges of the culture medium by simple carriage in streams set up by capillarity, and though a large number of organisms was present in the inoculum, there was definite increase in these as evidenced by the large numbers of organisms present in smears of material from various points round the margin of the plates.

Experiment 3.—Five sheep were fed for fourteen days on green field peas. A collective sample of faeces was used to prepare petri dishes of sterilized faeces as in Exp. 2. A plate was then sown with a loopful of dilution of broth culture of Preisz-Nocard bacilli, which contained the following numbers of organisms as determined by the plating out

method:—(a) 450, (b) 265, (c) 120, (d) 33, and (e) 2. (*Note*.—These counts can only be taken as a very approximate indication of the number of individual bacteria present in seeding material because of the characteristic spontaneous clumping of the organisms in cultures.)

Plates sown with all dilutions showed visible colonies at the site of inoculation from four to seven days after seeding. Portions of faeces removed from the margins of the plates, and sown on serum broth eight days and fifteen days after seeding in no case showed the presence of Preisz-Nocard bacilli.

In this experiment, although visible growth took place on the surface of the medium at the site of seeding, apparently no extension of growth through the substance of the medium to the margin took place.

Experiment 4.—Similar material was used to that employed in the preceding experiment, but instead of being placed in petri dishes, which were sown on the surface, the faeces were sterilized in test-tubes, and then seeded with the same dilutions of culture as used in Exp. 3. When examined after eight days incubation at 37° C., a definite marked increase was found to have occurred in all tubes, as determined by the method of plating out dilutions.

Experiment 5.—Faeces were collected separately from three sheep which had been fed on green cow-peas for fourteen days. This experiment was a repetition of Exp. 4, only a different lot of sheep was used, and the faeces from individual sheep were tested separately. Plates were incubated for eight days. In no plate did visible colonies appear, nor did the organisms appear to have grown through the substance of the medium, as portions of the medium taken from margins of the plates failed to show the presence of bacteria when sown in serum broth. Definite multiplication occurred, however, in tubes of mixed faeces from these three sheep sown with the same dilutions of culture at the same time as the plates. This may be explained by the greater quantity of water present in the tubes, the plates being somewhat drier than earlier batches.

Experiment 6.—Faeces were collected separately from two sheep which had grazed on green grass growing in a small paddock in the Laboratory. This grass was of the same composition as in Exp. 2c, only there was a young shoot after recent rains. Definite visible surface colonies developed five days after seeding in plates from both sheep. No growth through the substance of the medium in these plates was demonstrable.

Experiment 7.—Freshly voided faeces were collected from sheep which had been grazing on a pasture composed almost exclusively of subterranean clover. Plates and tubes were prepared, and sown with serial dilutions of culture. No surface growth was observed, but moderate growth occurred in the tubes as demonstrated by plating out on serum agar.

Experiment 8.—One sheep was fed on lucerne hay for ten days. Plates and tubes were prepared from faeces, and sown with serial dilutions of culture. Surface colonies developed on the plates, and definite growth occurred in the tubes, multiplication again being controlled by plating out on serum agar.

Experiment 9.—This was a repetition of 8, but a different sheep was substituted. Growth occurred both as visible surface colonies, and through the substance of the medium of the plates, and definite multiplication, controlled by plating out, was demonstrated in tubes.

Experiment 10.—Faeces from sheep fed on cow-peas were rubbed up in a mortar with tap water to form a thin porridge. This was then filtered through paper, and the filtrate passed through a Seitz EK filter pad. The filtrate thus obtained was found to be sterile. It was then tubed and seeded with dilutions of broth cultures of Preisz-Nocard bacilli. No growth took place after incubation at 37° C. for 20 days.

DISCUSSION.—These experiments prove conclusively that the Preisz-Nocard bacillus will grow in sterilized sheep faeces under certain conditions. It was thought at first that a diet of green leguminous plants was necessary to provide the required conditions in the faeces to support growth, but subsequently it was found that, besides green cow-peas and green subterranean clover, a diet of green grass proved a satisfactory one. The definite multiplication which took place in faeces from sheep fed on lucerne hay showed that it was not essential for the diet to be in the green state. Our experiments on the determination of the hydrogen-ion concentration of the faeces on different diets, though somewhat limited, have not indicated that the pH is the limiting factor. It is thought that possibly the protein content of the diet may be related to subsequent growth in faeces, animals on a diet high in protein allowing sufficient to pass out unabsorbed in the faeces to support the growth of the Preisz-Nocard bacillus. From the fact that seventeen different sheep were used in these experiments, and group results were always the same, it does not appear that the suitability of the faeces to support growth is an inherent quality of certain animals, but does definitely depend on the nature of the diet.

B. Sterilized Faeces in Competition with other Bacteria.

It must be pointed out that, though the results of the foregoing experiments are very suggestive, it cannot be safely concluded that such a multiplication of the Preisz-Nocard bacillus will occur in unsterilized faeces under natural conditions. Faeces contain a large number of bacteria of various kinds, which are particularly adapted to growth in such a medium, so that a rather slow-growing organism such as the Preisz-Nocard bacillus will have very great competition for the available nutriment in such faeces, and will run the risk of being overgrown by other bacteria such as *Bacillus coli*.

Up to the present, all our attempts to isolate the Preisz-Nocard bacillus from natural unsterilized sheep faeces have failed. Even though freshly voided faeces be experimentally contaminated with large quantities of Preisz-Nocard bacilli, we have been unsuccessful in recovering the bacillus again, owing to the rapid overgrowth by other faecal organisms. It has also been found that, if faecal material suspected or known to contain Preisz-Nocard bacilli is inoculated in small amounts into guinea-pigs, the latter succumb to infections by organisms normally present in faeces before any lesions can be produced by the Preisz-Nocard bacillus.

Although we have not been successful in carrying out experiments with unsterilized faeces, the following experiments were undertaken to ascertain whether the Preisz-Nocard bacillus could grow in sterilized faeces in competition with two common faecal bacteria, namely, *Bacillus coli* and *Staphylococcus pyogenes aureus*.

Experiment 1.—A collective sample of faeces was taken from three sheep which had been fed on green field peas for fourteen days. A

simultaneous experiment showed that definite multiplication of the Preisz-Nocard bacillus occurred in this sample after sterilization, and seeding with the Preisz-Nocard bacillus alone.

After sterilization, plates and tubes were prepared in the usual manner. A surface depression was made in the centre of each plate, with a sterile glass rod, and into this depression was then introduced dilutions of culture of the Preisz-Nocard bacillus and *Bacillus coli* in varying proportions. The tubes of faeces were sown in the same manner, and both series were incubated for eight days at 37° C. Plates were examined daily for surface growth, but none was observed throughout the period of observation. On the eighth day, portions of faeces at varying distances from the centre of the plates were examined microscopically, and also sown on serum agar.

Table 1 shows the various proportions of culture of each organism used for sowing, and the results.

TABLE 1.

Number of Plate or Tube.	Sown with—		Results.	
	Preisz-Nocard Bacillus 2 loops.	<i>Bacillus coli</i> 2 loops.	Plates.	Tubes.
	Dilution of Culture.	Dilution of Culture.		
1	1 : 1,000	1 : 1,000	<i>B. coli</i> ..	<i>B. coli</i> and P.N. bacillus
2	1 : 1,000	1 : 10,000	<i>B. coli</i> ..	<i>B. coli</i>
3	1 : 1,000	1 : 100,000	<i>B. coli</i> ..	<i>B. coli</i>
4	1 : 10,000	1 : 1,000	<i>B. coli</i> ..	<i>B. coli</i>
5	1 : 10,000	1 : 10,000	<i>B. coli</i> ..	<i>B. coli</i>
6	1 : 10,000	1 : 100,000	<i>B. coli</i> ..	<i>B. coli</i>
7	1 : 100,000	1 : 1,000	<i>B. coli</i> ..	<i>B. coli</i> and P.N. bacillus
8	1 : 100,000	1 : 10,000	<i>B. coli</i> ..	<i>B. coli</i> and P.N. bacillus
9	1 : 100,000	1 : 100,000	<i>B. coli</i> ..	<i>B. coli</i>
10	1 : 1,000,000	1 : 1,000	<i>B. coli</i> ..	<i>B. coli</i>
11	1 : 1,000,000	1 : 10,000	<i>B. coli</i> ..	<i>B. coli</i>
12	1 : 1,000,000	1 : 100,000	<i>B. coli</i> ..	<i>B. coli</i>

In the plates, *Bacillus coli* alone was demonstrated by direct microscopical examination of smears made from faeces at various distances right out to margin from centre of plates. This organism was also recovered in pure culture from the margins of plates. In no instance was the Preisz-Nocard demonstrated in any plate.

In three tubes (No. 1, 7 and 8), a few small clumps of Preisz-Nocard bacillus were demonstrated microscopically in smears made from the faeces, but attempts to recover this organism were unsuccessful in every tube, a pure culture of *Bacillus coli* resulting in every instance.

Experiment 2.—This was carried out in a similar manner to the preceding experiment, the same sample of faeces being used, and both experiments were run simultaneously. Tube cultures only were sown, plates being omitted.

The results are seen in Table 2.

TABLE 2.

Number of Tube.	Preisz-Nocard Bacillus 2 loops.	<i>Staphylococcus pyogenes aureus</i> 2 loops.	Results.
	Dilution of Culture.	Dilution of Culture.	
1	1 : 1,000	1 : 1,000	<i>Staphylococcus aureus</i> and P.N. bacillus
2	1 : 1,000	1 : 10,000	<i>Staphylococcus aureus</i> and P.N. bacillus
3	1 : 1,000	1 : 1,000,000	No growth
4	1 : 10,000	1 : 1,000	No growth
5	1 : 10,000	1 : 10,000	No growth
6	1 : 10,000	1 : 100,000	<i>Staphylococcus aureus</i>
7	1 : 100,000	1 : 1,000	<i>Staphylococcus aureus</i>
8	1 : 100,000	1 : 10,000	<i>Staphylococcus aureus</i> and P.N. bacillus
9	1 : 100,000	1 : 100,000	<i>Staphylococcus aureus</i>
10	1 : 1,000,000	1 : 1,000	<i>Staphylococcus aureus</i> and P.N. bacillus
11	1 : 1,000,000	1 : 10,000	<i>Staphylococcus aureus</i>
12	1 : 1,000,000	1 : 100,000	<i>Staphylococcus aureus</i> and P.N. bacillus

In this experiment, it is seen that growth of the Preisz-Nocard bacillus did take place in the presence of *Staphylococcus pyogenes aureus*, but growth was rather scanty, and, as seen, irregular.

The first of these two experiments indicates that the overgrowth of the Preisz-Nocard bacillus in unsterilized faeces is a definite possibility; the second experiment shows that the Preisz-Nocard bacillus is able to maintain itself in the presence of at least one of the common bacteria of sheep faeces.

3. Conclusion.

In view of the fact that growth occurs readily in certain types of sterilized faeces, it is our opinion that the possibility of the Preisz-Nocard bacillus leading an external saprophytic existence should still be seriously entertained, until such time as definite proof of its behaviour in this external medium in its natural unsterilized condition is forthcoming, and until we have proof to the contrary, we consider that every precaution should be taken to minimize the risk of infection of sheep from accumulations of manure, particularly in positions to which sunlight does not have direct access. We have proof from experiments to be published shortly that the Preisz-Nocard bacillus is able to survive in sterilized sheep faeces which are protected from direct sunlight for over a year. This fact, quite apart from the possibility of its growth in faeces, warrants definite steps being taken to prevent the accumulation of sheep faeces in such places as shearing sheds, counting out pens, covered holding yards, and the like.

The Production of Tannin Extract from the Kino-impregnated Bark of Marri (*Eucalyptus calophylla*).

By W. E. Cohen,* B.Sc.

In previous issues of the *Journal* (e.g., 1: 285, 1928; 2: 161, 1929) references have been made to the investigations carried out in co-operation with the Forests Department of Western Australia and with the University of Western Australia with a view to the development of a satisfactory process for the commercial production of tannin extract from certain products of the forest. In the last issue (page 169) reference was also made to the commercial exploitation of the results of these investigations in so far as they related to karri. Before it was closed down, the tannin extract plant was used to study the possibilities of the production of extract from the kino-impregnated bark of marri. An account of that work is given below.—ED.

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| 1. Introduction. | 4. Plant Experiments. |
| 2. A General Discussion of the Problem. | 5. Conclusion. |
| 3. Laboratory Experiments. | |

Summary.

Recent investigations have shown that, by a simple process, an extract of satisfactory quality can be made from kino-impregnated marri bark.

Previous investigations involved severe and expensive treatment in order to obtain a high yield of tannin free from insoluble matter, and the processes employed caused considerable darkening in colour which naturally affected the value and quality of the extract.

From a consideration of the relationship between temperature of extraction and yield of tannin and of "insolubles," it has been shown that a satisfactory yield of tannin is attainable at 60° C. Above this temperature, no considerable increase in tannin is obtained, but a substantial increase in the yield of sparingly-soluble matter occurs. The latter introduces difficulties with respect to clarification, solubilization, and the colour imparted to hide substance.

A survey of a large number of solubilizing or dispersing agents has shown that sodium bisulphite is the most suitable material. By extracting kino-impregnated bark at 60° C. and subsequently treating the infusions with sodium bisulphite at 100° C. and evaporating, a very satisfactory liquid extract has been made in a plant test. This extract has been used to produce leather which has been reported to be of good quality and to be readily saleable.

1. Introduction.

Marri, or Western Australian redgum (*Eucalyptus calophylla*), grows very abundantly in the south-west portion of Western Australia. The forest is approximately 350 miles long by 50 miles broad at the northern end, widening to 200 miles in the south. The tree occurs mixed with jarrah (*E. marginata*) and karri (*E. diversicolor*), but patches of pure stands of marri are quite frequent. Hence the collection of bark for the production of tannin extract can be carried out under conditions conducive to low costs. The timber has at present little or no commercial value on account of the extent and frequency of gum veins and pockets.

It should be noted that marri bark, except when impregnated with kino, is very low in tannin content, but that, where the kino-exudations occur, the bark becomes a valuable source of tannin. It is possible to collect large quantities of the kino-impregnated bark with a high percentage of tans, and

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this would form a substantial source of tannin extract if the problems of solution and decolorization were satisfactorily solved on a commercial basis. It will be necessary, however, to purchase bark on the basis of its tannin content, and, with respect to this, every care will have to be taken in the collection and preparation of samples because of the variations resulting from the irregular occurrence of kino-exudations.

Under the direction of the former Institute of Science and Industry and, more recently, at the Brunswick Laboratory of the Commonwealth Council for Scientific and Industrial Research, a large amount of experimental work on the production of a suitable extract was carried out by Salt† and Coghill.‡ In addition to these investigations, a number of attempts to commercialize marri kino as a tanning material have been made from time to time by commercial interests.

Some attempts at tapping kino-impregnated trees are recorded in the Annual Reports of the Western Australian Forests Department. Details of quantities available are recorded by Salt* and Coghill.†

2. A General Discussion of the Problem.

When kino-impregnated marri bark is leached with hot water and the resulting infusion strained to remove small particles of bark, &c., a clear hot liquor, which when cooled below 50° C. becomes exceedingly turbid, is obtained. On analysis, this liquor is found to contain cold-insoluble matter amounting to as much as 20 per cent. of the total hot-soluble matter present. In addition, the colour it imparts to hide substance is of a dirty brownish nature, and is not desirable in leather manufacture. Hence, with marri extract, the main problems are—

- (a) the elimination of matter insoluble in the cold either by removal or solubilization,
- (b) the removal or brightening of colour of those bodies which give rise to the dirty brown colouration or hide substance.

In the past, the solution of these problems has been attempted by autoclaving, at temperatures of 100° C. and higher, either picked kino or extract (prepared by leaching the kino or impregnated bark with hot water and evaporating the extract), with solutions of solubilizing agents such as the acid and normal sulphites of the alkalies or mixtures of these. This procedure was claimed to have been successful in part because solubilization was definitely effected. However, losses of tannin and degradation in colour occurred. This suggests that, apart from the expensive equipment employed and the severe processing required, the attempts to make a good commercial product were not altogether successful. In addition, it has been recorded that encouraging results were obtained by treatment of the kino with hot solutions of the above-mentioned reagents in open vessels.

At the outset of the investigations now under review, it was decided to seek the simplest process which would give a practical yield of good quality extract. Whereas previous investigations had aimed at maximum yields by severe processing, in this investigation quality and costs of production were placed before quantity. Hence, attention was given to the consideration of (i) the relationship between temperature of extraction and yield of tannin; (ii) solubilization by simple boiling with cheap reagents; and (iii) the elimination of the more difficultly-soluble bodies by sedimentation, followed

* Institute of Science and Industry, Circular No. 8 (1922).

† Council for Scientific and Industrial Research, Circular No. 9 (1927), and Council for Scientific and Industrial Research, Bulletin No. 32 (1927).

by decantation or filtration. As the result of these studies, a process was evolved and employed on a semi-commercial scale in order to manufacture approximately 2 tons of liquid extract of which over half was of a most encouraging quality. Further reference will be made to this extract later.

3. Laboratory Experiments.

(i) Relationship between Temperature of Extraction and Yield of tannin.

(a) *Under Analytical Conditions.*—A large bulk sample of finely divided kino-impregnated bark was prepared by using the laboratory bark mill and a 20-mesh screen. From this, a series of smaller samples were taken and extracted in duplicate, according to the procedure given in official methods of tan analysis, at various temperatures ranging from room temperature to 100° C. The infusions thus obtained were examined, by the official method, for total solids, total solubles, insolubles, tans and non-tans. Guided by preliminary extractions at the various temperatures, it was possible to arrange the samples of bark so that all the infusions were approximately at the same concentration, i.e., 4 grams of tannin per litre. Apart from temperature, all other conditions were kept uniform according to a standard procedure. The main results of duplicate tests, together with those of duplicate extractions carried out strictly according to the official method (i.e., 2 litres extraction in four hours), are set out in Table 1. In most cases, for the purpose of comparison, the colours of the infusions at 0.5 per cent. tans were determined by means of the Lovibond Tintometer, and these are recorded in the table. However, a better idea of the effect on colour was obtained by a comparative examination of the hide powder samples subsequent to the non-tan determinations.

TABLE I.—MARRI KINO. OPTIMUM TEMPERATURE OF EXTRACTION.

Temperature.	Total Solids.	Total Solubles.	In-solubles	Tans	Non-tans.	Ratio Tans to Non-tans.	Colour by Tintometer at 0.5 % Tans		
							Red.	Yellow	Blue
°C.	%	%	%	%	%				
Room temperature—									
16 ..	27.2	26.6	0.6	21.2	5.4	4.0	..	n.d.	..
30-40 ..	38.0	35.9	2.1	29.4	6.5	4.5	..	n.d.	..
40-50 ..	41.9	38.3	3.6	31.5	6.8	4.6	5.2	15.0	..
50-60 ..	43.9	38.2	5.7	31.9	6.3	5.1	4.9	20.5	..
60-70 ..	47.4	39.6	7.8	32.8	6.8	4.8	5.6	20	..
70-80 ..	47.7	39.8	7.9	33.3	6.5	5.1	6.3	26.3	..
80-90 ..	47.8	39.7	8.1	33.1	6.6	5.0	6.3	26.3	..
90-100 ..	48.5	39.6	8.9	32.8	6.8	4.8	7.1	27	..
100 ..	48.6	39.7	8.9	32.6	7.1	4.6	7.2	27	..
Official Method (2 litres—4 hours) ..	49.2	40.4	8.8	33.3	7.1	4.7	..	n.d.	..

By reference to Table 1, it will be seen that, at 70-80° C., the maximum extraction of tans was obtained, and that, by increasing the temperature, the extraction of sparingly-soluble matter (officially "insolubles") was increased and the colour intensified. At as low a temperature as 40-50° C., 95 per cent. of the tans were extracted, and the yield of sparingly-soluble matter was considerably less (41 per cent. of the total obtainable), and the

colour was both lighter and brighter. These results suggested that it would be preferable to work at moderate temperatures (say, 60° C.), leaving behind some of the difficultly-soluble material, for the sake of obtaining less turbid liquors and a better colour. Naturally, with less sparingly-soluble matter, the problems of solubilization and clarification would be simplified.

The question as to whether time of contact influenced the extraction as well as temperature was considered by studying the extraction at 70–80° C., using initial periods of contact of $\frac{1}{2}$, 1, and 2 hours, but no appreciable differences in the yields were obtained.

Another point, which was raised during the course of the above experiments, was the possibility of heat causing cold-soluble tannin to become difficultly-soluble. In order to study this aspect, a cold extraction of marri kino was made, and samples of the resulting solution were heated for one hour at various temperatures. The results showed convincingly that the readily-soluble material was entirely stable at these temperatures. It is a fact, however, that, when a clear strong liquor is heated, a precipitate is formed, but this readily re-dissolves on dilution and, therefore, is not an "insoluble" in the official meaning of the word. It is suggested that such a reaction results from the reversible coagulation of the soluble bodies at elevated temperatures.

The conclusions that were drawn from the above analytical studies were that extraction at elevated temperatures was entirely unnecessary, and that a satisfactory yield of tans could be obtained at moderate temperatures, such as 60–70° C. At the same time, the sparingly-soluble bodies, known as "insolubles," would not be leached out in such large quantities as they were by previous methods, and, on this account, the clarification and solubilization problems would be simplified. The experiments suggested the following avenues of attack —

- (a) Leaching at 60–70° C.
- (b) Clarification by sedimentation, followed by decantation or filtration.
- (c) Solubilization of the sparingly-soluble tans so that little or no loss would occur during the elimination of bodies still sparingly soluble (and not tannins in the official meaning) by sedimentation and subsequent processes.

Before proceeding with the above, it was decided to confirm the results indicated in Table 1 on a larger laboratory scale. Results obtained under strictly analytical conditions cannot always be repeated on a larger scale. Consequently, the temperature-yield relationship was again studied.

(b) *Temperature-yield Relationship under larger Scale Laboratory Conditions.*—For this purpose kino-impregnated bark was disintegrated in the plant bark-chopper-and-grinder employing a $\frac{3}{4}$ -in. screen. The resulting material varied in size from fine dust to particles which would not pass through a $\frac{1}{4}$ -in. sieve. Consequently, samples drawn from this would very likely have shown considerable variation. In order to minimize this difficulty, the whole sample was sieved into three grades, and each of these thoroughly mixed and weighed. For the actual laboratory samples these grades were taken in their original proportions.

The extractions were carried out according to the customary press-leach system, circulating the "forward" liquor (that which was in contact with the fresh charge of bark) for a period of two hours, so that the whole charge was uniformly at the working temperature, 60° C. It was considered, from

preliminary tests, that all materials extractable at this temperature would then be dispersed, only requiring displacement by weaker washes and finally by water, all at the same temperature, 60° C.

The leaches were carried out in copper beakers, fitted with perforated false bottoms, which were covered with butter muslin. Five such beakers constituted a battery, and the complete leaching of the battery a laboratory test. Each beaker could accommodate 1 lb. of bark together with the necessary amount of liquor (4-4½ parts to 1 part of bark). The ratio of liquor to bark was decided by the strengths of the resulting liquors. It was considered advisable to keep these below 50° barkometer (i.e., sp. gr. = 1.050) in order that large losses would not be sustained during decantation. Yields were determined by weighing and analysing all liquors and washes. Tests were carried out at 60° C., 80° C., and 100° C. In addition, a leach was made at 60° C., and all the resulting strong liquors were placed in tall cylinders in order that sparingly-soluble matter might settle out. In this case only the clear supernatant liquors were considered for the yield. The results served to confirm those obtained under analytical conditions. While the yield of tans was approximately the same for each test, the yield of "insolubles" increased considerably with temperature. The results obtained by clarifying the resulting liquors were of particular interest. They showed that sedimentation and decantation efficiently eliminated the "insolubles," but, without the aid of any solubilizing agent, the accompanying loss in tans was such that the procedure would be impracticable from the commercial point of view.

(ii) *Consideration of Solubilizing Agents.*

When it had been demonstrated that temperature control would greatly contribute towards the production of a useful extract, it was necessary to consider the question of a suitable solubilizing or dispersing agent to render the sparingly-soluble tans cold-soluble so that clarification could be achieved without much loss of tannin. A large number of possible reagents were considered from the following aspects:—

- (a) the degree of solubilization obtained ;
- (b) the assistance rendered to decantation and filtration in the elimination of "insolubles" ;
- (c) the colour of the resulting clarified liquors ;
- (d) the effect on ultimate yield ; and
- (e) the cost of reagent.

The following reagents were considered:—Sodium bisulphite, meta-bisulphite, hydrosulphite ("Hydros"), and sulphite, "Neradol N," "Maxyntan," "Ordavol 2G," "Tannol NNO," "Tannin F.C.," karri extract, "Celltan," and, in addition, the following mixtures:—Sodium bisulphite and "Tannol NNO," sodium bisulphite and "Tannin F.C.," sodium bisulphite and sulphite, sodium sulphite and "Tannol NNO."

Of the above, "Neradol N," "Maxyntan," "Ordavol 2G," karri extract and "Celltan" showed little or no solubilizing properties. The others solubilized to various degrees, the most satisfactory results being obtained from using sodium bisulphite and sodium sulphite (separately). Taking into consideration the above-mentioned aspects, sodium bisulphite (containing over 62 per cent. total SO_2 or 85-90 per cent. estimated as metabisulphite) was determined to be the most useful and convenient material. It was noted in the tests that the quality of the bisulphite considerably influenced sedimentation. With bisulphite of the above-mentioned quality, the "insolubles" settled out as a compact rubbery mass on top of which occurred

a thin layer of granular material. Decantation was very easily and effectively carried out under these circumstances, and, in addition, the rubbery mass promised to be a convenient filtering cake on a larger scale. With poorer quality bisulphite, the "insolubles" did not readily settle, but remained in partial suspension and rendered clarification somewhat difficult. Consequently, losses of tannin in solution occurred as the result of inefficient decantation. The influencing factor was undoubtedly the hydrogen-ion concentration of the resulting mixture of bisulphite and marri extract. Following the satisfactory results obtained with bisulphite as a solubilizer, some laboratory tests were made employing the reagent subsequent to extraction and prior to clarification by sedimentation and decantation.

(iii) *Laboratory Tests employing Sodium Bisulphite as an external Solubilizer.*

For these tests, the extraction was carried out according to the procedure employed in the temperature trials. The strong "forward" liquors were withdrawn after two hours' contact and circulation at 60° C., and were then treated with bisulphite at 100° C. for one hour, allowed to cool slowly, and, while still warm and clear, were poured into cylinders and set aside for a period of two to three days in order to permit the cold-insoluble matter to settle out. It was realized that, on a commercial scale, the treated liquors would cool very slowly, thus affording the bisulphite greater opportunities for dispersing the tannins and, in addition, retarding any sedimentation. This difficulty was overcome to some extent in the laboratory by heating the liquors in flasks immersed in a 10-gallon copper containing boiling water and allowing them to cool with the water in the copper. After cooling, the supernatant liquors were withdrawn by decantation, weighed, and analysed. The weaker washes, occurring at the end of each test, were not treated with bisulphite, but were weighed and analysed in order to be included in the yield determinations. If anything, this latter procedure adversely affected the results, because the "insoluble" content of the washes was proportionately greater than that of the treated liquors.

The quantity of bisulphite used was calculated as a percentage of the total solids contained in the liquor. In order to determine rapidly the total-solids content of a liquor, the barkometer strength at 50° C. was employed. As the result of a number of trials, a fairly definite factor, relating barkometer strength to total-solids content, was determined. At the working temperature, 50° C., all the sparingly-soluble material was still well dispersed, and, therefore, acted as solubles in the barkometer determinations. This temperature was also advantageous in that the delay necessary between the withdrawal of a liquor and its treatment with the solubilizer was reduced to a minimum. The method, at any rate, was sufficiently accurate for the purpose of approximately controlling the quantity of bisulphite used, and promised to be readily applicable on plant scale.

The results obtained from eight laboratory trials are set out in Table 2. There is obviously no definite gradation in these, due, in some measure, to the different conditions occurring from one test to another. Thus no attempt was made to standardize the limits to which each solution cooled, because no such procedure would be practicable on a large scale. The laboratory temperature varied considerably from week to week, and, consequently, the liquors of one run could easily have attained a lower minimum temperature than those of another during sedimentation and also at the time of decantation. These variable conditions naturally influenced the "insoluble" content when "insoluble" meant "not filterable at 20° C." It was, of course,

realized that the large quantities of liquor, obtained on a commercial scale, would not be so susceptible to local daily temperature variations. In addition, the samples of bark used in these tests varied slightly in analysis from test to test (see footnote, Table 2).

TABLE 2.—MARRI KINO-LABORATORY TESTS.

Extraction by press leach at 60°C. and treating liquors externally with bisulphite prior to sedimentation and decantation.

Bisulphite to total Solids.	Net Yield after deducting Reagents added (assuming Non-tans) % O.D. Bark.				Percentage Extraction Obtained.*			
	Total Solubles.	In-solubles.	Tans.	Non-tans.	Total Solubles.	In-solubles.	Tans.	Non-tans.
%	%	%	%	%	%	%	%	%
3 (a)	37.6	2.0	30.6	6.9	95	27	95	93
4 (d)	35.9	1.9	29.4	6.5	94	23	95.5	88
5 (b)	35.3	0.9	28.9	6.4	92.5	9.7	96.0	80
6 (c)	36.9	1.6	29.9	7.0	92	25	93	89
7 (a)	38.7	1.2	31.4	7.2	98	16	97.5	97
8 (a)	36.9	2.2	30.4	6.5	93	30	94.5	88
9 (c)	35.4	1.8	29.0	6.4	89	29	90	82
10 (b)	33.5	1.1	27.7	5.8	88	12	92	72.5

* Note.—Calculated from yield obtained and possible yield as indicated by the analysis of the bark using the official method.

Analysis of bark samples—

	Total Solids.		Total Solubles.		Insolubles.		Tans.		Non-tans.
(a)	47.0	..	39.6	..	7.4	..	32.2	..	7.4
(b)	47.4	..	38.1	..	9.3	..	30.1	..	8.0
(c)	46.3	..	40.0	..	6.3	..	32.2	..	7.8
(d)	46.0	..	38.2	..	8.4	..	30.8	..	7.4

The outstanding results were those in which bisulphite was employed in the proportions of 5 per cent. and 7 per cent. of the total solids present. The former provided a comparatively low yield of "insoluble" matter without any proportional loss in tans. As already indicated, this may have been due, in part, to local temperature conditions. It appeared that 5 per cent. to 7 per cent. of bisulphite could be advantageously used as an external solubilizer, the extra bisulphite affording greater bleaching facilities and, therefore, a brighter coloured product. When used in quantities above this proportion, acidity influenced the yield of tans adversely (see Table 2). The colour imparted to hide substance by the solutions obtained in these tests was highly satisfactory.

The results at this stage indicated a definite procedure for plant tests, viz., leaching at 60° C., and subsequent treatment of all "forward" liquors at 100° C. with bisulphite in the proportion of between 5 per cent. and 7 per cent. of reagent to total solids present.

(iv) *Laboratory Tests employing Sodium Bisulphite as an Internal Solubilizer.*

Before proceeding with plant tests to confirm the previous results, laboratory trials were made adding sodium bisulphite to the leach liquors during extraction and circulation. The procedure adopted for leaching, solubilization, and clarification was similar to that already described. The results showed the effect of the greater solvent power of the bisulphite solution at 60° C. Bodies, which were completely insoluble in water at 60° C., were leached out, thus affording much greater yields not only of tans and non-tans, but also of "insolubles" and red-coloured material. As a

result, clarification was not so readily accomplished, and the colours imparted to hide substance were not at all encouraging. Because of these latter difficulties, this procedure was not further investigated. However, if any work is attempted in the future, it is recommended that this treatment should be given further consideration. Possibly, the use of a minimum quantity of the reagent during leaching and the addition of more reagent preparatory to solubilization at 100° C. may afford more satisfactory results.

(v) *Laboratory Tests with Mixtures of Aluminium Sulphate and Sodium Bisulphite as External Solubilizers.*

Several references have been made in tannin extract literature to the possible use of mixtures of aluminium sulphate and sodium bisulphite for the dispersion of sparingly-soluble tans. According to the theories advanced, free sulphur dioxide is formed *in situ*, thus affording more concerted action of the reagent. In addition, the red-coloured tannins are supposed to form lighter-coloured aluminium salts. The formation of aluminium hydroxide and the introduction of its coagulating properties has been claimed to facilitate clarification. All these claims appeared to promise the solution to the problem of providing a light-coloured and clear marri extract, and the use of these mixtures was accordingly given some attention. The procedure adopted was similar to that when bisulphite was used alone. The results indicated that a considerable loss in tans occurred and that clarification was not effective, resulting in a high yield of insoluble matter. It should be mentioned, however, that the colour imparted to hide substance was very satisfactory, although solutions resulting from the bisulphite treatment gave equally encouraging results.

4. Plant Experiments.

(i) *General Discussion.*

The plant experiments to be described below were not completed before the termination of tannin extract investigations in accordance with a plan to concentrate the staff of the Division of Forests Products in Melbourne.

Owing to the limited time available, the plant experiments now under review were planned not so much to study the question of costs nor to indicate the most desirable technique in any great detail, but rather to confirm or disprove some ideas with reference to solubilization and clarification that had been formulated as the result of laboratory experience. In addition, it was hoped to overcome any difficulties which were not encountered in the laboratory tests, and to indicate the lines of attack for any future work that might be undertaken. The plant tests would also provide some sort of extract which could be used for subsequent decolorization and tanning experiments. Consequently, one short test was carried out before suspending operations entirely, and an account of this is given below.

(ii) *Preparation of Material.*

Kino-impregnated marri bark (9,110 lb.) was disintegrated[†] in a Van Gelder crusher and grinder, using both 1-in. and $\frac{3}{4}$ -in. screens. Of this, approximately 6,000 lb. were prepared while the latter screen was in use. The average moisture content was found to be 11 per cent., so that the moisture-free weight of material treated amounted to 8,100 lb. The disintegrated material was elevated to a hopper bin, from which it was discharged into tared bags and weighed. The experience gained during the plant tests showed that the material passing through the $\frac{3}{4}$ -in. screen was most readily handled and leached, since a larger percentage of fine kino was obtained, giving rise to a more rapid solution in water.

(iii) *Leaching of Material.*

Each vat was charged with 1,500 lb. of disintegrated material. The charges were sampled during the process by making a grab sample from each 100-lb. lot. The aggregate sample was then quartered down to a convenient size and ground for analysis by the official method. To be more thorough, each of these larger samples should have been graded and each grade separately quartered down. However, since the yield was not the most important factor to be studied during the plant run, this precautionary measure was not taken. It has already been mentioned that it was difficult to take two similar samples of the bark. Hence it was not surprising to find that the six samples obtained differed considerably.

To the 1,500 lb. of bark in each vat, 550 gallons of water or weak wash liquor (during continuous operations) at 60° C. were added. The temperature of the mixture was maintained at 55–60° C. for three hours by circulating the liquor through a tubular water heater. By this time the solution of all material soluble at this temperature was complete and the liquor was withdrawn, at the same time being replaced by weaker washes or water also at 60° C. The strong liquor was passed on to the next charge and the process continued as outlined above. The strong liquor resulting from this second extraction was found to run at about 30° barkometer at 20° C., and was withdrawn to the storage tank for subsequent treatment. The process was continued in the same way (i.e., press leaching at 60° C. with circulation in the forward vat and withdrawal of the strong liquor from each alternate vat) until all six vats had been leached.

It is necessary at this stage to discuss certain mechanical difficulties which were encountered during the leaching process. The ground bark consisted of light porous bark and finely ground denser kino, which readily softened in warm water before dissolving. Consequently, when the leach liquor was run into the vat the charge rapidly separated into two layers. The bark floated and was difficult to wet, and the kino formed a soft impervious layer at the bottom and prevented adequate circulation. It was necessary to break up this layer by means of poles before proceeding with the treatment. The problem appears to be purely mechanical in nature, but it will have to be surmounted before any future work along these lines is attempted. It is possible that the difficulty may be overcome by the simultaneous admission to the extraction vat of both bark and leach liquor through the agency of an intermediate mixing device. The gradual introduction of the bark to the leach liquor contained in the vat and rapid circulation so that the temperature (60° C.) is maintained by means of closed steam coils is also suggested. The admission of a small amount of live steam in advance of the leach liquor might bring about the desired wetting of the bark. A further suggestion is the introduction of a short cold leach preparatory to the admission of hot leaching liquor. Consideration could also be given to the question of finer disintegration of the bark. A mechanical separation of the bark from the gum and the separate treatment of each also presents a possible solution to the problem.

(iv) *Solubilization, Clarification, and Concentration.*

The strong liquors, upon withdrawal, were treated in large copper tanks with sodium bisulphite (containing 62 per cent. total sulphur dioxide or 85–90 per cent. estimated as sodium metabisulphite), using 4 parts to every 100 parts of solids in solution, in the case of the first two cases,* and 7 parts for the remaining four.

* Instead of awaiting the results of analyses, it was possible, from previous laboratory experience, to determine approximately the total solids content from the barkometer reading at 50° C. It was found, however, by subsequent analyses, that the laboratory factor differed from that required in the plant, because of the different bark stock used and consequently a different ratio of tans to non-tans. This matter was remedied, but not before the first two liquors had been treated. Consequently, these only received four parts of bisulphite instead of the five that had been intended.

When the bisulphite had been added to the liquor, the whole was thoroughly mixed and then heated by means of steam coils to 95–100° C. After standing overnight, the liquor was gravitated into a settling vat to permit the solid particles that were not dissolved by the bisulphite (i.e., fine bark, &c.) and those that were still cold-insoluble to settle. This vat was provided with a perforated copper false bottom, which was covered with hessian. The degree of cooling largely influenced the “insoluble” content of the resulting liquor and also the ultimate extract. Since it was midsummer when the experiments were carried out, it was very difficult to have liquors cooled below 27–30° C., whereas 20° C. would have been more desirable. When thoroughly cold (a matter of days, the actual time depending on local conditions), the liquor was slowly pumped from the vat through the false bottom. At this stage, conditions different from those experienced in the laboratory, but not in the least unexpected, were experienced. The large mass of liquor had cooled more slowly than the smaller quantities handled in the laboratory. Consequently, the bisulphite was afforded prolonged opportunities for solubilization. In addition, the same degree of cooling was not attained. These differences were responsible for the presence of only a small amount of insoluble matter at the bottom of the vat. Although this was hardly sufficient to provide a filtering cake, the withdrawn liquors were very clear, suggesting that the “insoluble” bodies had all been retained on the hessian. The clarified liquors obtained during the plant experiments were found to range from 35–38° barkometer.

By the treatment outlined above, there were no losses of soluble substances, but quantities of cold-insoluble red substances were most certainly either eliminated or dispersed. The clear liquors thus obtained were subsequently concentrated to approximately 250° barkometer in a double effect evaporator, run into casks, and stored. The evaporation presented no serious difficulties, but it was necessary to give fairly constant attention in order to effect such a concentration in two stages.

(v) *Consideration of Yields.*

It has already been mentioned that the plant tests were not planned to study the question of yields. However, some data were collected mainly to prove that no losses of tans were incurred during the clarification process. Reference has been made to the difficulties encountered in leaching and the necessity for the breaking up of the cake of kino in order to permit circulation. This naturally encouraged channelling, and it was not surprising, therefore, on emptying the vats to find large lumps of undissolved kino. Consequently, the yields indicated below should be largely improved upon when the leaching difficulty is overcome.

The average analysis of the six samples collected while charging the six vats, expressed on the moisture-free basis, was as follows:—

				%
Total solids	..	..	..	45.9
Total solubles	..	..	..	38.1
Insolubles	..	..	..	7.8
Tans	..	..	..	31.6
Non-tans	..	..	..	6.5
Ratio tans/non-tans	..	..	..	4.9

The total yield, determined by considering the quantities of liquid extracts obtained and their analyses, together with the quantities and

analyses of weak wash liquors that remained at the end of the test, expressed as percentages of the bark, on the moisture-free basis, was as follows :—

				%
Total solids	..	..	..	35·8
Total solubles	..	..	..	34·0
Insolubles	..	..	..	1·8
Tans	..	..	..	26·8
Non-tans	..	..	..	7·2
Ratio tans/non-tans	..	..	..	3·7

This, however, included the 166 lb. of bisulphite, or residual portion thereof, added for the purpose of solubilization. This represented 2·1 per cent. of the bark treated, but some of this was eliminated as sulphur dioxide during the solubilization boil and the evaporation. These losses could not be accurately accounted for, but an assumption that the residual part amounted to 2·0 per cent. of the bark in the yield results was regarded as safe. Again, it was very questionable whether the bisulphite residue could all be accounted for as non-tans. Hence, any definite expression of yield of tans and non-tans could not be made.

It could only be stated that the net yield, exclusive of bisulphite, was :—

				%
Total solids	..	..	..	33·8
Total solubles	..	..	..	32·0
Insolubles	..	..	..	1·8

Since the ratio of tans to non-tans in the bark was 4·9, and since laboratory results had shown that the tans were as readily extracted as the non-tans at 60° C., the extraction or yield ratio could have attained the above figure. By assuming 4·9, the following would have been the approximate yield :—

				%
Tans	..	..	..	26·6
Non-tans	..	..	..	5·4

and, hence, the percentage extraction would have been :—

				%
Total solids	..	..	..	73·6
Total solubles	..	..	..	84·0
Insolubles	..	..	..	23·0
Tans	..	..	..	84·0
Non-tans	..	..	..	83·0

With a solution to the leaching problem, it could confidently be expected that the percentage extraction yield of tans would exceed 90 per cent., and thus attain the standard of the laboratory results.

The yield of total solids and solubles was studied from another aspect. All strong liquors at withdrawal and prior to treatment, as well as the weak washes at the end of the test, were accurately measured and sampled. From these observations, the following yields were determined :—

				Percentage of moisture-free Bark.
Total solids	..	..	..	37·0
Total solubles	..	..	..	32·0
Insolubles	..	..	..	5·0

Hence, thanks to the solubilizer, the elimination of about two-thirds of the "insolubles" was accomplished, by dispersion and sedimentation, without any loss whatever of solubles.

The spent bark still contained a fair amount of soluble tans. This was naturally influenced by the inclusion of large pieces of kino which had caked and which had not been leached on account of the channelling which occurred during the process. Owing to its heterogeneous nature, accurate sampling and analysis of the spent bark were impossible. From the point of view of clarification, the plant tests were most satisfactory. They indicated, however, that a large capacity, in the form of settling vats, would be required on a commercial scale.

(vi) *Consideration of Liquid Extract obtained.*

The following are the analyses of the six liquid extracts obtained :—

TABLE 3.

Serial No.	Total Solids.	Total Solubles.	In-solubles.	Tans.	Non-tans.	Ratio Tans/Non-tans.	Colour at 0.5 % Tans. By Lovibond Tintometer.	
							Red.	Yellow.
	%	%	%	%	%			
1	46.3	43.5	2.8	34.6	8.9	3.9	11.5	28
2	47.8	45.1	2.7	36.2	8.9	4.2	9.6	25
3	51.1	49.4	1.7	38.7	10.7	3.6	10.3	20
4	49.3	47.4	1.9	37.0	10.4	3.6	10.6	25
5	48.2	46.6	1.6	36.6	10.0	3.7	10.6	25
6	51.0	49.3	1.7	38.6	10.7	3.6	10.6	25

Extracts 1 and 2 were obtained by evaporating liquors which had been treated with 4 per cent. of bisulphite (to total solids present). The other four were treated with 7 per cent. of bisulphite, and a marked improvement in the colour imparted to hide substance by the extract was noticed. The "insolubles" content was also considerably reduced. With reference to this there were probably a number of contributory causes.

(1) Increase in bisulphite.

(2) Owing to a heat wave, the first two liquors did not cool below 30° C. in five days. They were optically clear at this temperature, and were evaporated without further delay. In addition, the major portion of these liquors was decanted and not filtered through the hessian in the settling vat. The later liquors attained the minimum temperature of 26° C. and were all filtered.

(3) A certain amount of deposit from the evaporator tubes found its way into Extracts 1 and 2 before this trouble was noticed.

When the colours imparted to hide substance were considered, it was found that the extracts did not compare very favorably with the head liquors nor with the liquors obtained during laboratory tests, although they were still quite satisfactory. This was not unexpected, partly because of the sustained heating to which plant liquors were necessarily subjected, together with more complete solubilization, but mainly because of the elimination of all free sulphur dioxide during the solubilization boil and throughout the evaporation. That the sulphur dioxide and its bleaching

properties greatly influenced the colour imparted to hide substance was fully appreciated during the laboratory tests. The liquid extracts, on examination, were found to be entirely free from sulphur dioxide and almost free from sodium bisulphite.

Attempts to improve the colour of the extract prepared by using 7 per cent. bisulphite as solubilizer were subsequently made in the laboratory. A large number of reagents were tested, and these included organic and inorganic materials which have been mentioned in the literature as being efficient decolorizing agents. Several syntans were included in the tests, but without success. Blending marri extract with karri extract did not yield any fruitful results. The most satisfactory results were obtained by the addition of sodium bisulphite, hydrosulphite, or metabisulphite, or free sulphur dioxide to the extract. These were added in definite proportions related to the total solids content and the extract was heated to 50° C. Sodium bisulphite and sulphur dioxide were found to be the most satisfactory, mainly on the score of cost. The addition of an extra 1 per cent. showed marked improvement in colour, although it was considered that 3 per cent. gave the most satisfactory results. The above percentages are based on the total solids present.

It was concluded that the most satisfactory extract resulted from solubilization with 7 per cent. bisulphite and subsequent additions to the extract of 3 per cent. bisulphite or 1-2 per cent. of free sulphur dioxide. The total added material would therefore not exceed 10 per cent. of the total solids leached from the bark, or about 4 per cent. of the total bark extracted. The conditions in the case of a solid extract would naturally be somewhat different.

Several small samples of extract treated during these decolorization tests were prepared for tanning trials, but, to date, no facilities have been available for making these tests. The bulk of the extract obtained in the plant was not treated in this way, but was sold to a local tanner, who has reported very favorably on its behaviour.

5. Conclusions.

As the result of laboratory and plant scale tests, it has been shown that a satisfactory extract can be made from kino-impregnated marri bark. It would appear to be preferable to forsake 100 per cent. yield of tans in order to produce a brighter coloured and clearer extract. Leaching at 60° C. with water or weak washes and subsequent treatment at 100° C. with sodium bisulphite, amounting to about 7 per cent. of the total solids, followed by settling, has been found to yield clear, bright-coloured liquors which can be concentrated to a clear extract with a satisfactory colour. The colour of the latter may be further improved by the addition of small quantities of sodium bisulphite or of sulphur dioxide.

Certain difficulties have still to be overcome, the main one occurring in the leaching process, but this appears to be simply of a mechanical nature.

Foot and Root Rots of Wheat in Australia.

Fusarium culmorum (W.G.Sm.) Sacc. as a Causal Organism.

By W. L. Geach,* B.Sc.

Summary.

1. Numerous cultures of *Fusaria* were isolated from foot-rooted wheats obtained from various wheat-growing areas in the Commonwealth. Many of the *Fusaria* were found to belong to the group "Discolor."

2. Of the *Fusaria* of the "Discolor" group, *F. culmorum* (W. G. Sm.) Sacc. was identified. Two isolations of *F. culmorum* were selected and compared with a culture of this organism from Saskatchewan, and close agreement regarding the measurement of sporodochial conidia was obtained.

3. A number of wheat varieties were inoculated with transfers from these cultures, and the pathogenicity of the organisms was established, both in the glasshouse and in the field, after preliminary trials on plants grown in artificial media in large glass tubes.

4. *F. culmorum* produced typical foot-rot symptoms, including the condition known as white heads, usually attributed to *O. graminis*.

5. Of the eighteen varieties of wheat so far tested, none showed immunity to the isolations of *F. culmorum* used in the experiments reported in this paper.

1. Introduction.

The group of wheat diseases to which the names foot-rot, root-rot, take-all, white heads, and others are variously applied, is the most economically important in Australia. Brittlebank (4) of Victoria, writing on this subject, states, "Of all the fungus diseases affecting wheat, 'take-all' is the most destructive, and the actual loss caused by it is far greater than by any other single disease, rust included, or perhaps by a combination of all known fungus diseases affecting wheat in Australia." In a recent publication, Hynes (8) reports that foot-rot is one of the most serious diseases in New South Wales, and he gives several instances of 30%–50% losses. Carne (5) also reports 30%–50% reduction in estimated yield in some districts in Western Australia, and states that 10% loss is common. In an anonymous article in the *Journal of the South Australian Department of Agriculture* (1) written in 1906, a year when the disease was unusually severe, it is stated:—"In some cases the prospective yield of a whole district is reported to have diminished 30%." Mackinnon (10) considers the loss throughout the Commonwealth caused by take-all to average 7% per annum. The writer estimates a crop reduction of 30%–75% in some fields visited by him during the past season. Estimating the average annual yield reduction at the very conservative figure of 2½% of the total wheat crop, the loss for Australia as a whole based on a five-year average of production and prices amounts to about £750,000 per annum. It is probably much greater.

According to the literature, the organisms associated with the disease complex in Australia are *Ophiobolus graminis*, Sacc., *Wojnowicia graminis* (McAlp.) Sacc., *Helminthosporium sativum*, P.K.B., *Rhizoctonia* sp., *Brachysporium* sp., and occasionally mention is made of *Fusaria*. In 1921, Hamblin (6) working on *Helminthosporium*, noted the frequency of occurrence of *Fusaria* in his isolations, but

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no mention was made of attempts to determine their importance. In 1924, Hynes (7) recorded the occurrence of *Gibberella saubinetii* (Mont.) Sacc. in New South Wales when he identified perithecia on oat-stubble as those belonging to that organism. On plating out some of the perithecia, he obtained cultures of a *Fusarium* which agreed with the description given for the conidial stage of *G. saubinetii*, but he was, however, unable to obtain the perfect stage in pure culture. He showed that this organism was pathogenic on wheat and other cereals, producing foot-rot symptoms.

Numerous cultures of *Fusaria* of the "Discolor" type* have been isolated by the writer from diseased wheat plants obtained from many districts in the principal wheat-growing areas of the Commonwealth. Specimens from the Wimmera district, particularly, have yielded almost without exception cultures of *Fusaria* macroscopically similar to isolations identified as *F. culmorum*, although this organism has not been reported hitherto as causing foot-rot of wheat in Australia. In 1896, McAlpine (9) described *F. culmorum* (McAlp.) as occurring in salmon-coloured patches on wheat, particularly at the nodes and on the ears, but he did not give an opinion regarding its pathogenicity. According to Simmonds (11), *F. culmorum* causes seedling-blight and foot-rot of oats in Canada, and Bennett (2) reports it as a cause of foot-rot of wheat in Great Britain.

The object of this paper is to record the occurrence of *F. culmorum* (W. G. Sm.) Sacc. in Australia as a causal organism of foot-rot of wheat, to show that it is pathogenic not only in the glass-house, but also under field conditions, and to indicate its importance in this country. Studies of the effect of environmental factors on the incidence of the disease, and testing of numerous wheat varieties for relative resistance, are now in progress.

2. Source of Material.

The State Departments of Agriculture of New South Wales, Victoria, South Australia, and Western Australia very courteously co-operated by sending in specimens of foot-rotted wheats to the Division of Plant Industry at Canberra during the past two years. Those from the 1931 crop were obtained from seven districts in New South Wales, seventeen in South Australia, ten in Victoria, and six in Western Australia. Several hundred diseased plants were also collected by the writer and others from the New South Wales wheat areas of Wagga, Coolamon, Junee, Temora, Wyalong, Young, and Cowra.

3. Isolation and Identification of Organism.

Isolations were made from lesions on the roots and on the basal portions of the stems. The selected portions were washed in water to rid them of loose earth, immersed in 70% alcohol for 1½ minutes, washed in sterile water, transferred to potato-dextrose agar in petri dishes, and a drop of 5% lactic acid added around each piece of material to prevent growth of bacteria. After a few days, portions of the developing fungi were transferred to potato-dextrose agar in tubes.

Several hundreds of "Discolor" *Fusarium* isolations were made, and a number of them were studied culturally and microscopically.

* In this paper the term "Discolor" is applied to those *Fusaria* which, when grown on potato-dextrose agar, produce bordeaux, rose, honey, and white coloured hyphae, accompanied by the production of bordeaux pigment in the agar.

Although the cultures appeared to be of similar appearance macroscopically, certain differences were noticed when they were more closely examined, and therefore, with the object of arriving at some satisfactory and rapid way of grouping them by comparison of their gross characters, they were grown on a variety of media, including potato-dextrose, plain potato, oat, wheat, salts glycerin, starch asparagin agar, melilotus stems and potato plugs. Such attempts, however, gave unsatisfactory results, since perplexing variations occurred under similar environmental conditions.

No perithecia were observed in any of the cultures, although many attempts were made to induce their formation.

Two of the isolations were selected for the studies reported in this paper. One of them was from the wheat variety "Purple Straw" from Longerenong, Victoria, indexed in the writer's collection as F. 23, and the other from the variety "Federation" also from the Wimmera district, indexed as F. 30. Incidentally, it may be mentioned that a species of *Helminthosporium* (probably *sativum*) was also isolated from the material from which F. 23 was obtained.

A culture of *F. culmorum* from Saskatchewan, Canada, and the two isolations F. 23 and F. 30 were grown at the same time and under the same environmental conditions on sterilized melilotus stems, and measurements of the sporodochial conidia of all three cultures were made. In the following table, it will be seen that the conidial measurements of the Australian isolations showed close agreement with the Saskatchewan culture.

TABLE I.—MEASUREMENTS OF SPORODOCHIAL CONIDIA.

Number of Septa.	<i>F. culmorum</i> (Saskatchewan).	Percentage of each Type.	F. 30.	Percentage of each Type.	F. 23.	Percentage of each Type.
5	34.5 x 5.2 μ	26	33.9 x 4.79 μ	33	34.07 x 4.73 μ	53
4	32 x 4.7 μ	49	30 x 4.9 μ	34	30.33 x 4.3 μ	24
3	28.8 x 4.7 μ	23	26.7 x 4.34 μ	32	25.22 x 4.4 μ	23
2	..	..	25 x 5 μ	1		

Subcultures of F. 23 and F. 30 were finally submitted to Dr. H. W. Wollenweber of the Biologische Reichsanstalt für Land- und Fortswirtschaft, Berlin-Dahlem, Germany, who identified them as *F. culmorum* (W. G. Sm.) Sacc.

4. Inoculation Experiments.

(i) *Preparation of Inoculum and Grain.*—Wheat grain with about an equal volume of water, was sterilized in Erlenmeyer flasks at 15 lbs. pressure for 45 minutes on two successive days. On this medium, the isolations F. 23 and F. 30 were grown in quantities sufficient for soil inoculation. Kernels of the wheat varieties to be sown were soaked over-night in water, and surface-sterilized by steeping for three minutes in a 50% alcohol solution containing mercuric chloride (0.2%), as recommended by Bennett (2).

(ii) *Inoculation of Plants in Pure Culture.*—As a preliminary to glass house and field trials, wheat plants were grown in large glass tubes

18 in. x. 2 in. on a medium made by adding 2% agar to the pH 6.2 culture solution of Brenchley, Maskell and Warrington (3). Five surface-sterilized kernels were placed on the surface of the agar in the tubes and a small quantity of the inoculum added.

Although this method involved the growth of the host plant under artificial conditions, it served a useful purpose, since all organisms other than the selected one were excluded, the condition of the root system of the plants could be observed, and it was possible conveniently and quickly to obtain some idea of the relative virulence of the isolations tested.

The wheat varieties grown in the tubes with the inocula F. 23 and F. 30 respectively, were rapidly attacked and killed. A number of other isolations of similar macroscopic appearance were also tested against wheat plants in this manner with essentially similar results. Other plants in tubes in which common saprophytic fungi such as *Macrosporium*, *Mucor* or *Penicillium* were allowed to grow, showed no foot-rot symptoms.

(iii) *Glasshouse Experiments.*—The soil used in these experiments consisted of five parts of river sand and three parts of white sand, thoroughly mixed and afterwards sterilized for four hours by steam at atmospheric pressure. An equal amount of soil was put into each container, also previously sterilized. The grains, surface sterilized by the method already indicated, were planted at a depth of $\frac{3}{4}$ in., and a piece of inoculum about the size of a wheat grain placed in contact with each before covering with soil. Fourteen varieties of wheat were used in these experiments. Ten grains of each variety were inoculated with F. 23, and ten of each with F. 30. Twenty grains of each variety served as checks for both sets of experiments.

A weighed quantity of a sterilized gravel mulch was spread over the soil to conserve moisture. Water was weighed in to the extent of the field-carrying capacity of the soil used, and the loss by evaporation made up once a week.

Results of the experiment, after six weeks' growth, are given in Table 2. It will be observed from the figures given in the control column that the average germination capacity of the grain was good, except in the case of the varieties "Major" and "Ford". Comparing the control figures with those in the column headed F. 23, it will be seen that this organism was responsible for a relatively large amount of disease which was partly manifested as seedling-blight and partly as blighting before emergence. The same symptoms were also observed on the plants inoculated with F. 30 but the percentage of infection, as indicated in the table, was lower than that produced by F. 23.

In a number of cases where no plants appeared after germination was general, the grain was dug out and examined, and in many instances it was seen that although germination had begun, the fungus had attacked and killed the developing seedlings before their appearance above the soil. Some plants grew to a height of one to two inches, then yellowed and died back. The region around the foot of such plants was rotted and of a deep brown colour. Isolations from the dead and dying plants gave pure cultures of a *Fusarium* indistinguishable in general appearance from F. 23 and F. 30. No foot-rot was observed in the controls.

Other wheat varieties were also tried and the isolations were found to be pathogenic on them.

TABLE 2.

Wheat Variety.	Inoculum F.23. 10 Grains Sown.		Inoculum F.30. 10 Grains Sown.		Controls. 20 Grains Sown.		Average Germina- tion Capacity Per 10 Seeds.
	Healthy Plants Remaining at end of Experiment.	Plants diseased, Dead, or did not appear above Ground.	Healthy Plants Remaining at end of Experiment.	Plants diseased, Dead, or did not appear above Ground.	Healthy Plants Remaining at end of Experiment.	Plants diseased, Dead, or did not appear above Ground.	
Baroota Wonder ..	6	4	8	2	19	1	9.5
Sunset ..	1	9	3	7	18	2	9
Ford ..	0	10	4	6	11	9	5.5
Bunyip ..	0	10	6	4	19	1	9.5
Currawa ..	1	9	7	3	19	1	9.5
Nabawa ..	0	10	1	9	17	3	8.5
Canimbla ..	0	10	4	6	17	3	8.5
Sands ..	4	6	7	3	19	1	9.5
Major ..	0	10	6	4	11	9	5.5
Dunmore ..	0	10	8	2	19	1	9.5
Geeralying ..	2	8	5	5	17	3	8.5
Hard Federation ..	2	8	7	3	16	4	8
Joffre ..	2	8	5	5	19	1	9.5
Caliph ..	2	8	8	2	18	2	9

5. Field Trials.

Trials were also made in field plots. The soil was inoculated and the grain sown on July 1st, September 9th and October 8th. The first two sowings were in rectangular areas subdivided into plots measuring 3 ft. x 2 ft. Six plants of each of four varieties were sown in each plot, of which there were twenty-one. Three of the plots were picked at random for controls. The last sowing was arranged differently, the grain being sown in six rows with approximately 200 grains of each variety per row. Observations were made from time to time, and as the plants approached maturity, striking differences were noticed between many of the inoculated plants and the controls. The majority of the control plants were moderately well developed, and of normal appearance, whereas the plants growing in the artificially inoculated soil were in many cases severely stunted and almost rotted through at the base of their culms. A number of plants showed the typical white head symptom, usually attributed to *O. graminis* (Plate 2). On examination, the ears were found to contain either shrivelled grain, or none at all.

All diseased plants from the first plot sown, and a number from the other plots were taken to the laboratory and material selected for plating. In nearly every case, cultures were obtained of a *Fusarium* of the same macroscopical appearance as F.23 and F.30. The controls were also carefully examined, but very few plants showed foot-rot lesions. Pieces of material showing these lesions were plated and cultures were obtained of *Fusarium* and other organisms. The

occurrence of foot-rot in the check plants was expected, as the soil was known to harbour foot-rot organisms. Observations on the reaction of the varieties to the inocula F. 23 and F. 30 are given in Table 3.

TABLE 3.

Inoculum F.30.		Inoculum F.23.	
Wheat Variety.	Observations.	Wheat Variety.	Observations.
Baldmin ..	Medium to severe infection	Ford ..	Medium to severe infection
Bena ..	Slight infection	Florence ..	Medium to severe infection
Bobin ..	Many plants severely foot-rotted	Firbank ..	Slight to very severe infection
Moirra ..	Slight to severe infection	Cleveland ..	Slight infection

It is concluded from the results of the field trials that the incidence of foot-rot was due principally to *F. culmorum* with which the soil was inoculated at the time of sowing.

6. Acknowledgment.

The writer desires to express his appreciation of the valuable assistance given in the preparation of this paper by Dr. H. R. Angell, Senior Plant Pathologist, Division of Plant Industry, C.S.I.R., Canberra.

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The Nomenclature of Australian Soils.

By J. A. Prescott, M.Sc., and J. K. Taylor,† M.Sc., B.A.*

During the course of soil surveys carried out by the Division of Soil Research during the past three or four years, it has been customary to denote the soil types encountered by means of numbers and letters pending a more general knowledge of the distribution and relative importance of the various soil types recognized. The basis for the definition of any given type has been the soil profile, usually to a depth of 6 feet or to parent rock, soils having profiles uniformly similar in every respect belonging to the same type, while minor variations within the profile could be treated as phases of the type. With increasing experience, it is now becoming possible to give the types recognized specific names, and the binomial system of the United States Department of Agriculture, which has recently been discussed by Lee,⁽¹⁾ has proved to be the most convenient for this purpose. The authors have also been in correspondence with Dr. C. F. Marbut, of Washington, and Professor C. F. Shaw, of California, on the subject. In this system, each soil type receives a "series" name, a geographical term defined by the locality where the type was first recognized or where the soil is most typically developed, and a class name defining the texture of the surface soil, this texture being determined both from field and laboratory examination of the type. No attempt has been made as yet to place closely related soils into "families" or similar associations, but generally speaking each soil type can be readily placed into one of the major soil groups.

Although the word "series" is used for the preliminary grouping of soils having a common profile except for the texture of the surface soil, many soil series contain only one or two soil types, and the use of the word is somewhat unfortunate in that it tends to confuse newcomers to the subject, and obscures the fact that soils belonging to several different series may be just as closely related as soils belonging to the same series. This does not, however, detract from the fundamental soundness of the system.

An examination of the soils so far defined on a profile basis in Australia reveals the fact that each of these recognized soil types conforms either to a soil type as defined by the United States of America system, to a phase of a soil type, or occasionally to a new type within the same family. It has, therefore, proved possible to give names to most of the types already recognized, and the series names have been registered with Professor C. F. Shaw, of the University of California, in his capacity as registrar for the International Society of Soil Science. The following table gives a list of names of the types now recognized, together with references to their published description. In a few cases, recognized types are not sufficiently important to justify naming at the present stage.

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TABLE 1.—DETAILS OF THE NAMES OF RECOGNIZED SOIL TYPES WITH REFERENCES TO DESCRIPTIONS AND OBSERVED OCCURRENCE.

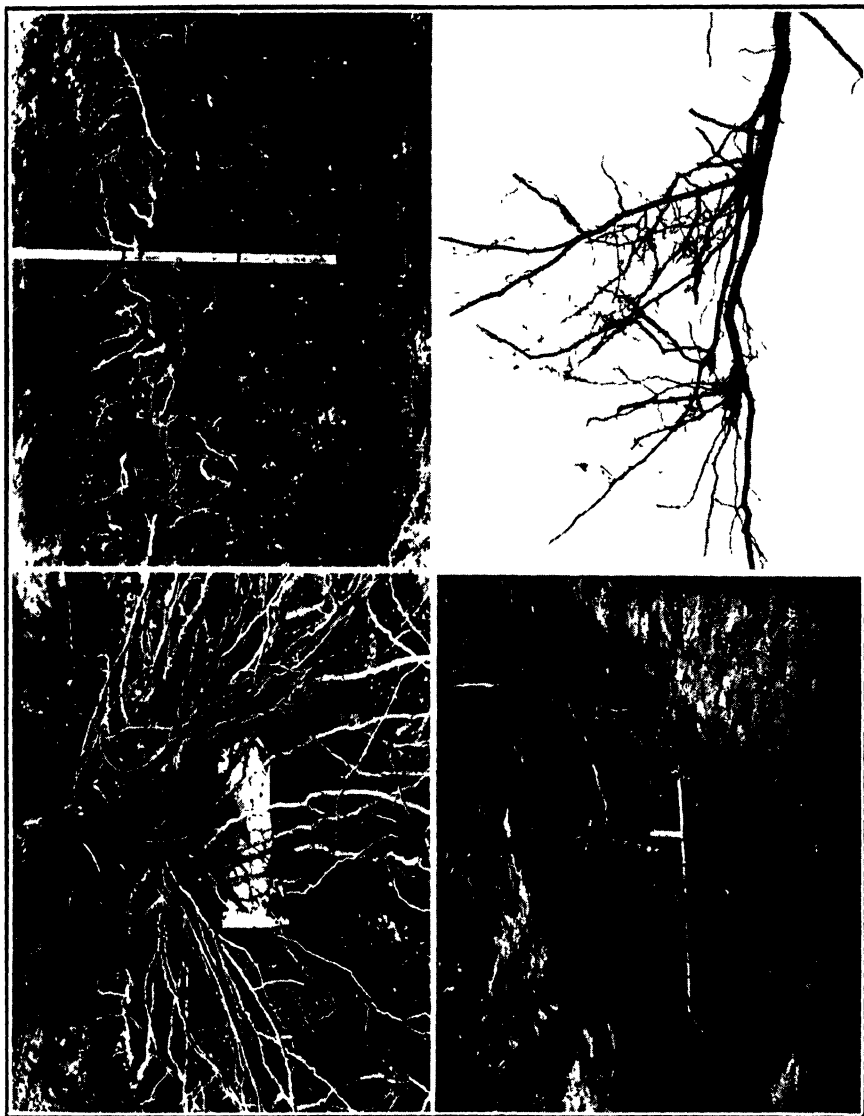
Original Type No.	Soil Type Names.	Phases.	Observed Occurrence.	References.
1	Murray sand .. ..	.. ..	Renmark (S.A.) .. Mildura (Vic.) Swan Hill (Vic.)	(2), (3) (5)
2	Mobilong clay ..	(a) Deep (normal)	Lower Murray River	(4)
2A		(b) Medium	Swamps (S.A.)	
2B		(c) Shallow		
3	Bookmark sandy loam ..	.. ..	Renmark (S.A.) ..	(2), (5)
3A	Bookmark clay loam ..			
5	Ral Ral sandy loam ..	.. ..	Renmark (S.A.) ..	(2), (5)
5A	Ral Ral clay loam			
5B	Ral Ral loam			
6	Renmark loam ..	.. ..	Renmark (S.A.) ..	(2), (5)
6A	Renmark clay loam			
6B	Renmark sandy loam			
7	Woorinen loam ..	.. ..	Swan Hill (Vic.) ..	(3)
9	Beverford clay loam ..	.. ..	Swan Hill (Vic.) ..	(3)
10	Swan Hill clay ..	.. ..	Swan Hill (Vic.) ..	(3)
..	Millicent clay ..	(a) Shallow .. (b) Deep (normal)	South-Eastern District (S.A.)	(6)
..	Meadows sand ..	.. ..	Hd. of Kuitpo (S.A.)	(7)
..	Meadows fine sand			
..	Meadows clay loam			
..	Kuitpo gravelly sandy loam	.. ..	Hd. of Kuitpo (S.A.)	(7)
..	Myponga sand ..	.. ..	Hd. of Kuitpo (S.A.)	(7)
..	Burbook sandy loam ..	(a) Normal .. (b) Shallow, stony	Hd. of Kuitpo (S.A.)	(7)
..	Currie calcareous sand ..	.. ..	King Island ..	(8)
..	Yambacoon sand ..	.. ..	King Island ..	(8)
..	Nugara sandy loam ..	.. ..	King Island ..	(8)
..	Pegarah fine sandy loam	.. ..	King Island ..	(8)
..	Naracoopa sand ..	.. ..	King Island ..	(8)
..	Lappa sand	King Island ..	(8)
..	Taroona sand	King Island ..	(8)
..	Camp Creek sandy loam	King Island ..	(8)

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PLATE 1.

(The Root System of the Sultana. See page 88.)



Top left.—A profile at a distance of 2 ft. 6 in. from the butt of a vine.

Top right.— Portion of a main root of a Zante Currant vine. The ascending tendency of the laterals and the effect of injury by the plough are shown.

Bottom left.— The butt of a Sultana vine eight years old.

Bottom right.—The root system of a Zante Currant vine during the course of excavation, showing horizontal spread of roots. The root system of the Currant is very similar to that of the Sultana.

PLATE 2.

(Foot and Root Rots of Wheat in Australia. See page 123.)

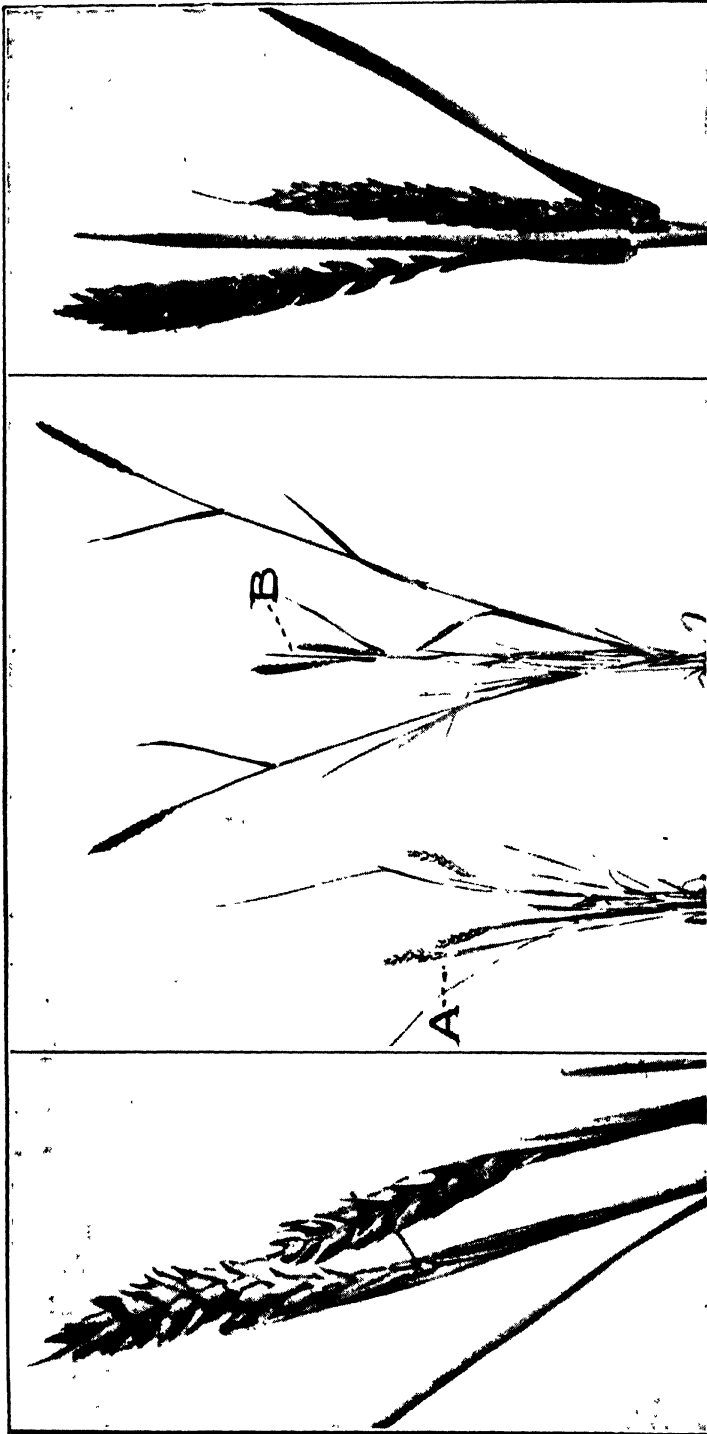


FIG. 3.

FIG. 1.

FIG. 2.

FIG. 1 (A).—Plant affected by foot-rotted plants of "Baldwin" wheat.
(B).—Healthy plant of *Fusarium culmorum* (F23), showing stunting and white head symptoms.

FIG. 2.—Ears of diseased plant. A enlarged to show white heads (nearly natural size).

FIG. 3.—Ears of normal plant B.

NOTES.

Co-operative Investigations into the Problems of the Cattle Industry of North Australia.

As yet, little information has been published regarding the co-operative investigations that have recently been initiated into the various problems of the cattle industry of North Australia. However, now that active work on these problems is about to commence, a brief account of the whole scheme of investigation and of the considerations that led up to its formulation may be of interest.

The proposal began to take shape some years ago when the Empire Marketing Board offered to contribute towards the establishment of a Tropical Research Station in Australia, on a £1 for £1 basis and up to a maximum of £25,000 for capital and £5,000 per annum for maintenance over a period of five years. This offer was made shortly before the holding of the 1927 Imperial Agricultural Research Conference, which, among other things, supported in general the establishment of a "chain" of tropical research stations throughout the Empire.

The scheme was given very careful consideration by the Council (for Scientific and Industrial Research), but as time went on it became increasingly evident that Australian conditions and problems did not warrant quite the kind of station the above-mentioned Conference had in mind. For instance, although quite a large proportion of Australia lies within the Tropics, yet the greater part of that area is comparatively dry and does not possess the luxuriant vegetation of normal tropical regions. Moreover, it became evident that the problems of North Australia were problems connected with the production of animals rather than the production of plant products. Finally, many of the authorities consulted came to the conclusion that it would be better for the Council to establish sub-stations in Queensland to undertake investigations on different tropical problems and to arrange for the efforts of these sub-stations to be controlled by the Council through its various Divisions, rather than to establish a new and independent large station which would after all be concerned with the same branches of science as those already covered by the Divisions.

As a result of these and other considerations, the proposal to establish a Tropical Research Station was modified in the direction of concentration on the animal side as distinct from the plant side. Finally, after numerous discussions between the Empire Marketing Board, the Government and other interested organizations in Queensland, the following scheme of co-operation was agreed upon by all parties.

Co-operating Bodies.—In the first place, Queensland cattle-owners have voluntarily requested their State Government to levy on them to the extent of 1s. per 100 head of cattle they possess. This levy is being made under "The Diseases in Stock and Brands Act, Amendment Act 1931", and all cattle owners possessing less than 100 head are exempt. In this way, approximately £2,000 per annum is being made available for the work.

In addition, the Queensland Department of Agriculture and Stock is making available the sum of £1,000 per annum, which amount it was previously expending at Townsville. It is also making available its laboratory at Townsville. The necessary alterations to this building

are now being made, but they are expected to be complete within a month or so. Finally, the Council of Agriculture in Queensland is also making a contribution of £300 per annum for five years.

All the above contributions are being matched on a £1 for £1 basis by a grant from the Empire Marketing Board, which grant itself is for a period of five years and up to a maximum of £5,000 per annum.

Staff.—The initial staff of the laboratory will consist of A. W. Turner, D.Sc., D.V.Sc., as Officer-in-charge, John Legg, D.V.Sc., R. B. Kelley, B.V.Sc. (Field Officer), and A. D. Campbell, B.V.Sc., Assistant Bacteriologist. In addition a laboratory assistant and a station foreman will be appointed. Dr. Turner left for Townsville in January. Prior to that, he was located at the Veterinary Research Institute, Parkville, where among other things he was responsible for the carrying out of the Division of Animal Health's investigations into black disease of sheep. With the exception of Dr. Legg, the other members of the staff followed Dr. Turner a little later. Dr. Legg has been seconded to the Council from the Queensland Department of Agriculture and Stock, and is now in South Africa inquiring into developments that have taken place there and in particular at the Onderstepoort Veterinary Research Station, regarding ticks and tick-borne diseases.

Programme of Investigations.—The problems which have been included in the initial programme are as follows:—

(i) Ticks and tick fever; (ii) pleuro-pneumonia of cattle; (iii) tuberculosis of cattle; (iv) peg leg disease; (v) walkabout disease in horses; (vi) black leg; (vii) onchocerciasis (worm nodules); and (viii) internal parasites.

In the first year or so, the main problems studied will be (i) to (iv) above, but in periods of low incidence or as the occasion offers, due attention will be given to the other problems mentioned.

(a) *Tick and Tick Fever.*—Prior to his visit to South Africa, Dr. Legg had already carried out a considerable amount of work on this problem. On his return, it is proposed that he will make a further study of the tick and those blood parasites conveyed by it in Northern Australia. It is obvious that a knowledge of these parasites is necessary in order that satisfactory immunising agents may be prepared. In addition to this phase of the problem, it is proposed to study what appears to be a natural resistance of certain strains of cattle to ticks, and also certain natural conditions—particularly as existing on one or two stations in Western Australia—which for some hitherto undetermined reason appear to be natural deterrents of the tick.

(b) *Contagious Pleuro-pneumonia of Cattle.*—It is proposed to make a further study of diagnostic methods and their practical value, and the degree of immunity induced by a natural infection from which recovery has apparently taken place, in order to determine whether infection ever does clear up and re-infection occur. Exhaustive tests regarding the efficacy of vaccines are considered to be urgently necessary, and if of real value the possibility of discovering more satisfactory means of preparation of such vaccines would be studied.

(c) *Tuberculosis in Cattle.*—The present theories as to the means of spread of contagion do not seem adequate to explain the high incidence found on certain tropical properties. Investigations from this point of view are therefore proposed both in the laboratory and in

the field. These will be supplemented by tests with vaccine particularly that known as B.C.G. and later on it is hoped with the Spahlinger vaccine.

(d) *Peg-leg Disease*.—The evidence available points to this disease, which affects cattle, being due to a nutritional disorder and possibly a lack of phosphorus. To some extent, however, the evidence is conflicting. It is therefore proposed to study the symptoms, pathological changes, &c., in order that a practical means of preventing the appearance of the condition may be developed.

(e) *Walkabout Disease and Poison Plants in General*.—Walkabout disease of horses causes considerable inconvenience to station activities in certain parts of Queensland. The condition as it occurs in Western Australia has been investigated by the Council (see Bulletin No. 36), and as a result, consumption of whitewood by horses is considered to be the cause. In some parts of Queensland, however, the results of this work are evidently not applicable in their entirety. It is accordingly proposed to carry out some investigations at Townsville as occasion offers.

In addition to whitewood, there are various other poisonous plants affecting the cattle industry of the north; and as comparatively little work has been carried out on the matter, it is proposed to investigate various suspected plants.

(f) *Black-leg*.—This disease is of no little importance, particularly in Central and Southern Queensland, amongst stud and dairy calves. A solution of the problem would thus be of considerable value to the dairy industry of Queensland.

(g) *Onchocerciasis (Worm Nodules in Cattle)*.—This disease is one of the most severe taxes on the export beef trade that Australia has to contend with. A considerable amount of investigation has already been devoted to the problem by Australian workers, but the assumed insect vector has not yet been discovered.

(h) *Advisory Committee*.—It is proposed to set up a small Advisory Committee representative of all the co-operating organizations to advise generally in connexion with the above work which is to be carried out at Townsville as the main centre.

Investigations on the Storage and Transport of Meat.

In the previous issue, a short note dealing with the Council's recently established section of food preservation and transport was given. The section's programme of work on meat and meat products is to be put in hand almost at once, largely as the result of facilities made available by the Queensland Meat Industry Board. The following is a brief account of the proposed investigations and their objects.

The laboratory where this work will be undertaken is being established at the Brisbane Abattoir, Cannon Hill, Brisbane, and will probably be complete in July next. The buildings and equipment will be erected at the expense of the Meat Industry Board, while the Council (for Scientific and Industrial Research) will supply and maintain the necessary research workers. Being linked so closely with a modern meat works erected to deal with the export as well as the local meat requirements, it is believed that adequate facilities will be available to study any pressing problem connected with the treatment side of the meat industry, and that the usual time lag between the successful solutions of these problems and their application to industry will be greatly reduced.

The laboratories will consist of two rooms fitted for bacteriological, chemical, and physical investigations, and several cold chambers specially fitted to secure strict control of temperature, relative humidity, and the composition and rate of movement of the enclosed atmosphere.

The problems initially to be studied may be summarized as follows:—

Chilled Beef.—Unless Australia is able to supply consumers overseas with beef in a condition closely resembling the fresh article, it is probable that export will continue to diminish in volume; at present the chief outlets for frozen beef in Great Britain are by contracts with military, naval, and poor law authorities, very little passing into general public consumption. Moreover, it is unlikely that the export of packaged quick-frozen cuts of beef will be commercially possible, at least for many years to come. Investigations designed to secure the export in the chilled condition of a considerable proportion of Australian beef would, therefore, seem to be essential if Australia is not to withdraw from the beef exporting trade.

The investigations will be concerned initially with the nature and extent of the deterioration of the fat and flesh of beef held at temperatures approximating to 30 deg. F. for periods up to 60 days in duration. Because microbial attack is likely to be the most serious factor in deterioration, investigations will also be undertaken to determine the best methods of handling and treating sides of beef prior to chilling. Concurrent with these studies, others will be undertaken to determine the optimum temperature, relative humidity, rate of air movement, and composition of the atmosphere necessary during both the initial cooling of the sides and the period of holding at “chill” temperatures to suppress microbial growth for a period of storage of 55 to 60 days. If these small scale experiments enable beef to be stored successfully for this period (sufficient to cover the duration of the voyage to Great Britain), the tests will be projected on to a semi-commercial basis.

The Handling, Freezing, and Storage of Edible Offal.—Investigations will be undertaken with the view to preventing the formation of “freezer and storage burn,” and to secure, in the thawed product, a texture more closely resembling fresh, unfrozen offal.

The Freezing, Storage, and Thawing of Bacon Pigs.—Although experiments in England have indicated that it is possible to manufacture good bacon and hams from frozen pigs, there are several studies still needed to be carried out, more particularly in regard to the maximum possible duration of storage of the frozen pigs, the optimum temperatures of storage, and the best method of thawing. Studies in conjunction with one or several Departments of Agriculture, will be needed to determine the type of fat to be developed in the pig to withstand successfully the onset of rancidity during the chain of treatment of freezing, storage, thawing, curing, and smoking.

By-Products.—Further investigations on the rapid freezing of cuts of meat and on the treatment of endocrine glands and other organs for the subsequent manufacture of pharmaceutical preparations may be carried out in close co-operation with the Low Temperature Research Station, Cambridge, England.

General.—It is hoped that eventually the resources of the laboratory will permit of studies being undertaken of any phase of meat works technique, including physical investigations of the engineering side which, up to the present, has been developed almost entirely by empirical methods. It might also be mentioned that it is hoped

later to initiate experiments at this laboratory which may aid in the elimination of the wastage occurring in the transport and handling of tropical fruits, and also extend the range of tropical fruit exported from Queensland.

The Export of Australian Meat—A Trade Union's Gift for Research.

The bodies co-operating in the above note dealing with the investigations at Cannon Hill, Queensland, have recently received most welcome encouragement in the form of a spontaneous gift of £50 from the Queensland Branch of the Australasian Meat Industry Employees' Union. In forwarding a cheque for this sum, the branch secretary wrote as follows:—

"In order to add our mite to furthering the efforts of your Council and to do our bit for the meat industry, I am directed to forward you the enclosed cheque for fifty pounds (£50), and to inform you that my Union will make a further contribution at a later date."

The Buffalo Fly Problem—Liberation of the Parasitic Wasp *Spalangia* sp.

The Council's Division of Economic Entomology hopes very shortly to liberate in North Australia a consignment of the parasitic wasp (*Spalangia* sp. (BzC))* with a view to ascertaining whether the widespread use of that variety of insect would be of value in the possible control of the buffalo fly.

As explained in the article, "The Buffalo Fly in Australia," which appeared in a previous issue of the *Journal* (Vol. 4, No. 4, 1931), it is recognized that no parasite can ever be expected to eradicate the fly completely, but nevertheless it is hoped that the introduction of the natural enemies of the fly will reduce its abundance to such an extent that it can no longer be considered as a serious menace to the cattle industry. Attention was first drawn to the possible value of *Spalangia* by Dr. Nieschulz, of the Veterinary Institute, Buitenzorg, Java. This reference was contained in a report made to the Council some years ago, the investigator mentioned then referring to the parasite as "BzC."

An abundance of evidence has been made available to the Council to the effect that the buffalo fly (*Lyperosia exigua* de Meijere), although it exists throughout the Netherlands East Indies, is not the pest there that it has become in North Australia. The importation of this wasp into Australia is not likely to be followed by any untoward results, as no species of the genus *Spalangia* is known to cause any economic damage, and the genus as a whole is to be regarded as comprising a group of beneficial insects. Some species have, in fact, already been found in Australia, and there is one in the Northern Territory which is known to parasitize puparia of *Lyperosia*. However, the species of which a hybrid race is now to be introduced is the most abundant and widespread so far discovered in the Netherlands Indies. It does not attack buffalo fly only, but is also parasitic on the puparia of other flies, e.g., *Musca*, *Biomyia*, &c. Nevertheless, it seems to prefer the buffalo fly.

The first district for the liberation work is to be Burnside Station, Brock's Creek, North Australia. Professor E. Handschin, of the

* Actually a hybrid race of *Spalangia* will be liberated, this hybrid being one of the crosses obtained from mating the Javanese species 'BzC' with the Australian species AC.

University of Basle, who has been in charge of the investigation in Java for the last two years, arrived in North Australia with a consignment of these insects in April last. As soon as it is quite certain that this shipment is free from secondary parasites, it is proposed to breed the wasps in numbers and to liberate them in the district.

The Buffalo Fly Problem—Co-operation of the Veterinary Services of the Netherlands East Indies.

With the transfer of Professor Handschin to Australia in order to make the liberation of *Spalangia* referred to in the previous note, the investigational work being carried out in the Netherlands East Indies by officers of the Council has been closed down, at any rate, for the time being.

Throughout their stay of some years in Java, the investigators have been freely afforded most helpful co-operation by the Veterinary Service of that country, and in particular have been accommodated at the State Veterinary Institute at Buitenzorg, where the whole resources of that Laboratory have been placed at their disposal.

With the closing down of the work, the Prime Minister has asked His Majesty's Consul-General at Batavia to convey to the Government of the Netherlands Indies the warm appreciation and thanks of the Commonwealth Government "for the advice and assistance which Dr. Van Eyck, as Director of Veterinary Services of the Netherlands Indies, Dr. C. Bubberman, as Director of the State Veterinary Institute, and their colleagues, Dr. B. J. Krijgsman and Mr. Pinto, have so helpfully and so ungrudgingly given to those officers in the service of the Commonwealth of Australia who have been pursuing investigations in Java into the problem presented by the buffalo fly."

A Sheep Branding Fluid Non-injurious to Wool.

(Contributed by D. Murnane, B.V.Sc., Division of Animal Health).

It is well known that the question of evolving a sheep branding mixture which meets the requirements of the wool-grower and at the same time is non-injurious to the wool (i.e., is easily removed in scouring operations) has been engaging the attention of the British Wool Industries Research Association for some time. The position has been more fully explained in a previous article (this *Journal*, February, 1931, p. 33), in which it was stated that the association recommends for use in Australia a mixture of the following composition:—

Wool fat	30	parts by weight
Resin	22	" "
Carnauba wax ..	3	" "
Kieselguhr ..	18	" "
Ignited iron oxide ..	6	" "
Emco spirit to desired consistency.		

While branding fluids made up to this formula are apparently quite satisfactory from the wool-scourer's point of view, they have been criticized in Australia on the ground of illegibility. That this criticism is not always warranted is made evident by the result of the following test.

In June, 1931, a number of shorn comeback wethers at the Veterinary Research Institute, Parkville—a portion of which is the Melbourne laboratory of the Division of Animal Health—were branded with a mixture made up according to the Association's formula given

above. Since branding, the sheep have been continuously exposed to the weather. Ten months have elapsed, and the brands are now plainly visible and equally as good as control brands on the same sheep made with a well known and commonly used black proprietary marking fluid.

Co-operative Horticultural Research—Root Stocks of Apples.

For some time past, certain problems have existed in connexion with the production of apples in Queensland, and particularly in the Stanthorpe district. Mr. R. G. Hatton, Director of the East Malling Research Station, who visited the district during his recent visit to Australia (see this *Journal*, Vol. 3, November, 1930, page 240), is of the opinion that the troubles are due very largely to the use of inappropriate root stocks. Incidentally, Mr. Hatton was rather impressed during his visit with the possibilities that existed in Australia for the application of the results of the researches that have been carried out under his direction at East Malling.

The matter has recently been discussed with the Manager of the Queensland Committee of Direction of Fruit Marketing, and as a result the Trustees of the Science and Industry Endowment Fund have arranged to appoint a research student to spend twelve months at the East Malling Station. After that, he will return to Australia, join the staff of the Council, and carry out some investigations at Stanthorpe. The Committee of Direction has agreed to meet the cost of his salary for the three years subsequent to his return to Australia.

The Part Played by Termites in the Destruction of Commercial Forest Trees—Report by Mr. G. F. Hill.

It has been suggested that there may be some association between heart rot and termite attack of ash trees (*Eucalyptus* spp.), and with the object of ascertaining whether this is the case, some preliminary investigations have been made in the Brindabella Mountains, Federal Capital Territory, by Mr. G. F. Hill, of the Division of Economic Entomology, Canberra. The results are recorded in a report recently received from the Division.

The evidence so far gathered does not support the view that there is any such association as that mentioned above; it was found, however, that many apparently healthy trees were rendered commercially valueless as a result of termite damage. Ninety-four per cent. of the larger trees (over 10 inches diameter) examined were found to harbour termites, whereas 4 per cent. only of the smaller trees (4 inches to 10 inches diameter) were infested. Five species of termites were found in ash trees (*E. gigantea* and *E. fastigata*), of which number only one, *Porotermes adamsoni*, is considered to be of major economic importance. (Fifty-eight per cent. of the large trees examined were found to be attacked by this species.) In most cases it appeared that the insects had gained access to the tree at a point near the ground where the trunk showed external evidence of fire damage. In all, about 450 living trees were examined in the F.C.T., of which number about 42 per cent. were found to be more or less damaged by the thirteen species of termites which were recognized. The habits of the more important species are discussed in the report, and photographs are appended to illustrate various types of damage.

The distribution of *Porotermes* coincides more or less closely with that of species of ash, which in New South Wales, Victoria, and

Tasmania are known to be seriously damaged by this termite. Further investigations are being made in the F.C.T., and it is suggested that these should be extended to include one of the principal ash forests of Victoria, where the losses due to "heart rot" are considerable.

Pine Aphis.—Liberation of Parasites.

In a previous issue (Vol. 4, November, 1931, page 254), reference was made to the damage caused to plantings of exotic pines (e.g., *Pinus radiata* (*insignis*)) in Australia by the pine Chermes* (*Pineus pini*). It was also stated that the Division of Economic Entomology was looking into the question of parasites likely to check the pest. Some progress has been made with that work, and recently a parcel of two varieties of insects, namely, *Hemerobius stigma* and *Leucopis obscura*, has been brought to Australia from England. Both these insects belong to a recognized class of entirely beneficial insects, and are incapable, from their structure, of doing any harm to economic plants since their larvae are predatory in insects, and are confined to Chermes and allies as hosts. For example, the larva of *L. obscura* is a legless grub which attacks Chermes and feeds upon them by piercing them and sucking them (or their eggs) of their contents. It grows rapidly, and when mature pupates beneath the woolly covering of its dead hosts.

After having been examined to be sure that they were true to name and free of parasites, the individuals of *Leucopis obscura* have been liberated on scale-infested trees in the Federal Capital Territory. Unfortunately, all the individuals of *Hemerobius stigma* died shortly after their arrival at Canberra. These particular individuals were sent in the adult stage, however, but within the next few weeks a further supply, this time consisting of eggs, will reach Australia.

Czecho-Slovak Academy of Agriculture.

Through the Consul-General for the Czecho-Slovak Republic, the Council has recently received a copy of a booklet describing the various activities of the Czecho-Slovak Academy of Agriculture. Arrangements are now being made for an interchange of literature between the two bodies.

The primary aim of the Academy, which was established in 1926, is the promotion of agricultural research and the practical application of its results in Czecho-Slovakia. Its activities are divided within the scope of six sections and of numerous working committees. The six sections already established are those of farming, forestry, horticulture, fruit growing and viticulture, agricultural industries, economics, and literature and culture.

The chief publication of the Academy is the C.A.A. Bulletin (Vestník). Comprehensive summaries in English, French, and German are included in each issue, and give the gist of all of that number's contents likely to be of interest to foreigners.

The Academy is housed in a commodious building in Prague. Its management is in the hands of a Presidential Council, which is elected

* In the previous note this insect was referred to as the pine aphis (*Chermes pini*).

for a period of three years. It consists of a President, two Vice-presidents, and a General Secretary. Membership may be divided into three categories—

- (1) Honorary membership awarded for permanent service to agriculture. The number of honorary members is limited to 40, half of whom may be foreigners.
- (2) Corresponding membership. This is limited to foreign experts, and they are elected at the annual general meeting.
- (3) Active membership is limited to Czecho-Slovak subjects who have done outstanding work in agricultural science, or who have contributed to rural cultural progress and agricultural production.

Recent Publications of the Council.

Since the last issue of the *Journal*, the following Bulletins and Pamphlets of the Council have been published:—

Bulletin No. 59.—"Radio Research Board: Report No. 2," by A. L. Green, M.Sc.

The investigations of the Radio Research Board have for their object the acquirement of knowledge of the propagation and characteristics of artificially and naturally generated electro-magnetic waves, with particular regard to those used in or affecting radio communication in Australia. The work described in Bulletin 59 has been carried out in pursuance of that object. The Bulletin itself consists of two papers, one entitled "The State of Polarization of Sky Waves," and the other "Height Measurements of the Heaviside Layer in the Early Morning."

The investigations have proved of no little interest in that they have confirmed an important hypothesis in connexion with the Heaviside Layer, namely, that whereas the polarization of a wave reaching the earth after reflection from the layer in the Northern Hemisphere has been found to be circular with the sense of rotation left-handed, the polarization of such a wave in the Southern Hemisphere would still be circular, but with the sense of rotation right-handed. No work on this particular matter had previously been ever carried out in the Southern Hemisphere. The investigations have also resulted in the discovery that one property of down-coming radio waves, namely, their polarization, is reasonably constant from night to night.

Bulletin No. 60.—"Radio Research Board: Report No. 3—The Influence of the Earth's Magnetic Field on the Polarization of Sky Waves," by W. G. Baker, B.E., B.Sc., and A. L. Green, M.Sc.

The Bulletin consists of a theoretical discussion of the earth's magnetic field on the propagation of sky waves of broadcast frequencies in the Heaviside Layer. The fundamental value of the report lies in the additional light it has thrown on the behaviour of radio transmissions once they have left the emitting station. Incidentally, it is interesting to note that authors predict that at night radio direction-finders in the Southern Hemisphere will be liable to much smaller errors of bearing when the direction-finder is situated to the north of the transmitter than when it is to the south.

Pamphlet No. 25.—"Termites (White Ants) in South-eastern Australia," by Gerald F. Hill.

The publication gives a simple method of identification of the varieties of white ants found in south-eastern Australia, and also a

discussion of the different ways these insects damage timber and forest trees. The pamphlet was written with the principal object of providing a reliable guide to foresters and others interested in the forest flora of Australia on the subject of the damage caused by termites or white ants. A further objective of the paper is to interest a large number of forestry workers in these insects, in the hope that they will collect them more frequently and send in their specimens to Mr. Hill for identification. With these ends in view, the paper has been written in simple language, and such scientific and technical terms as are unavoidably used have been defined in a glossary.

Pamphlet No. 26.—"The Irrigation of Horticultural Community Settlements," by A. V. Lyon, M.Agr.Sc.

This pamphlet was prepared largely at the instance of a representative conference on the dried fruit industry, which met late in 1930, and which considered that one way in which the industry could be helped would be by assisting the various Irrigation Advisory Boards, firstly, by furnishing them with technical advice concerning the periodicity of irrigation; and, secondly, by carrying out a programme of investigational work in regard to frequency and method of irrigation as affected by soil type, climate, and crop requirements. The publication, which was prepared mainly for the guidance of Advisory Boards in the Murray Valley settlements, presents data indicating the nature of the main controlling factors leading to possible waste at the present time. It also contains suggestions regarding the initiation of corrective measures.

Forthcoming Publications of the Council.

The following publications of the Council are now in the press:—*Bulletin No.* —"Studies in Supplementary Feeding of Merino Sheep for Wool Production, I." By Hedley R. Marston.

Bulletin No. —"The Ripening and Transport of Bananas in Australia." By W. J. Young, D.Sc., L. S. Bagster, D.Sc., E. W. Hicks, B.A., B.Sc., and F. E. Huelin, B.Sc.; and in part by R. A. Holloway, B.Sc., B.E., and O. P. Barr, B.E., of the New South Wales Government Railways.

Bulletin No. —"Radio Research Board: Report No. 4" 1. A Preliminary Investigation of Fading in New South Wales, by A. L. Green, M.Sc., and W. G. Baker, B.E., B.Sc. 2. Studies of Fading in Victoria: A preliminary Study of Fading on Medium Wavelengths at Short Distances, by R. O. Cherry, M.Sc., and D. F. Martyn, Ph.D., A.R.C.Sc. 3. Studies of fading in Victoria: Observations on Distant Stations in which no Ground Wave is Received, by R. O. Cherry, M.Sc.

Bulletin No. —"A Soil Survey of the Cadell Irrigation Area and New Era, South Australia." By T. J. Marshall, B.Sc. (Agr.), and A. J. King, A.A.C.I.

Pamphlet No. —"The Possibilities of the Zebu Cross in connexion with the Cattle Industry of North Australia." By R. B. Kelley, B.V.Sc.

Pamphlet No. —"The Pig Industry. Report on observations in Great Britain and America with possible Australian Applications." By R. B. Kelley, B.V.Sc.

(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 5.

AUGUST, 1932.

No. 3.

The Mineral Content of Pastures.

Report on Co-operative Investigations in Progress
at the Waite Agricultural Research Institute.

By Professor A. E. V. Richardson,* M.A., D.Sc.

1. Introduction.

In 1927, the Empire Marketing Board agreed to undertake, in co-operation with the Council for Scientific and Industrial Research and the University of Adelaide, an investigation of the mineral content of pastures.

The investigations were commenced in July, 1927, but owing to the lack of laboratory facilities in the earlier stages, it was not possible to appoint the full staff contemplated under the agreement until 1929, when the permanent laboratories were available. The full-time staff engaged on this investigation comprises three chemists, two agrostologists, two agronomists, one plant physiologist, and four botanical assistants.

The original objective of the investigation, as approved by the Empire Marketing Board, included three distinct phases of work:--

(a) *Field Investigations—Study of Mineral Deficient Areas.*

The investigation of the composition of pastures with special reference to areas in which mineral deficiencies existed, and the most economic method of correcting these deficiencies.

In view of the particular significance of phosphorus to Australian agriculture, special consideration was to be given to the rôle of phosphorus in pasture production. Field tests were to be included to determine the effect of various phosphates on—(i) yield, (ii) botanical composition, (iii) chemical composition, and (iv) nutritive value of the herbage.

(b) *Factors Affecting Mineral Content of Pastures.*

The investigation, under controlled conditions, of the mineral intake of pasture plants at varying stages of growth, and of the factors affecting the mineral content of pastures.

* Director, Waite Agricultural Research Institute, University of Adelaide.

(c) *Factors Affecting the Water Requirements of Pasture Plants.*

In view of the special significance of rainfall to pasture production in the semi-arid regions of the Empire, an investigation of the relationship between mineral intake of pasture plants to photo-synthesis and transpiration at varying stages of growth was to be undertaken, together with the general problem of the factors affecting the water cost of producing pastures.

The results of the investigation have been set out in a series of papers, some completed and others in the form of progress reports, for the information of the Empire Marketing Board and the C.S.I.R.

2. Field Investigations.

Before undertaking a detailed investigation of pastures in mineral deficient areas of Australia, it was considered desirable to make an intensive study of a typical natural pasture representative of the winter rainfall region, and to follow the changes in seasonal productivity, yield of mineral nutrients, botanical composition of the pasture whilst it was grazed by sheep, and to determine the precise influence of soluble phosphate on natural pasture.

(i) *Effect of Soluble Phosphate on the Productivity, Stock-carrying Capacity, and Chemical Composition of Natural Pasture at the Waite Institute.*

For this purpose, 50 acres of natural pasture at the Waite Institute were subdivided into ten paddocks each of 5 acres. Six paddocks were left in the natural condition, and four were top-dressed with soluble phosphate at the rate of 2 cwt. superphosphate per acre for three years.

Two flocks of Merino sheep have been maintained for three years on four of the unfertilized paddocks, and two flocks on the four paddocks treated with superphosphate, whilst one flock was alternately grazed on two untreated paddocks and received a phosphatic lick as a supplement to the unfertilized pasture.

Throughout the period, monthly records have been taken of the productivity, botanical composition and chemical composition of the pasture, the live weight gains of sheep, and the yield and quality of the wool.

The results of this investigation to August, 1931, are described in detail by Messrs. Davies, Scott, and Fraser in the paper "Investigations into the Mineral Content of Natural Pasture." Their main conclusions are as follows:—

Applications of superphosphate to natural pasture increased the hay yield by 65 per cent., whereas sown pasture, similarly treated, gave a yield of hay 108 per cent. greater than that of natural pasture.

Superphosphate induced profound changes in the botanical composition of the pasture and in the plant succession.

At all times, the percentage of phosphorus was higher in the pasture of fertilized paddocks than in the controls, the mean increase being 47 per cent.

Nitrogen was found to follow the same course as phosphorus, but the increased nitrogen content was due mainly to the altered botanical composition of the pasture.

The nutritive level of the herbage consumed by the sheep was highest from May to September, from which date there was a steady decline in nutrient value. The live weights of sheep reflect these changes in the nutritive value of the pasture.

Applications of superphosphate to the pasture did not change the weight of fleece or the quality of the wool, but as the number of sheep maintained on the manured pasture was 60 per cent. greater, the yield of wool per acre was increased in the same proportion.

(ii) *Effect of Equivalent Dressings of Phosphate as Water Soluble, Citrate Soluble, and Insoluble Phosphate on Natural Pasture.*

An area of natural pasture at the Waite Institute was set apart for the investigation of the effect of equivalent quantities of phosphoric acid (40 lb. per acre, and in the form of superphosphate, rock phosphate, basic slag, and as superphosphate plus nitrogen) on the yield, botanical composition, ecological succession, and grazing value of natural pasture.

Messrs. Trumble and Fraser set out the results in detail in a paper entitled "The Effect of Top-dressing with Artificial Fertilizers on the Annual Yield, Botanical Composition, and Carrying Capacity of a Natural Pasture."

They found that, with the exception of rock phosphate, each fertilizer substantially increased the yield of herbage throughout the seven years. During the sixth and seventh years, the increases due to superphosphate and nitrate of soda, and to basic slag, were maintained to a much greater extent than superphosphate alone. The herbage was profoundly altered by soluble phosphates, and a succession of miscellaneous exotic species was induced in what was formerly a *Danthonia* dominant pasture.

(iii) *Effect of Phosphate on Natural Pasture in a Phosphate Deficient Region.*

An area of typical pastoral country deficient in phosphate was selected at Kybybolite (256 miles south-east of Adelaide), and the effect of phosphate on the yield, botanical and chemical composition of the natural pasture, and the live-weight increase and yield and quality of the wool of Merino sheep was investigated. The preliminary results are summarized by Dr. J. Griffiths Davies.

The effect of superphosphate applied annually to natural pasture markedly increased the yield of herbage; and the botanical composition of the pasture was profoundly modified. The change is a progressive one, and the major effect is the stimulation of the annual elements in the sward. The annual clovers are greatly stimulated in the first three or four years. Following the development of the clovers, there is a progressive increase in the annual grasses, which ultimately become dominant.

The live weight of sheep carried per acre is greatly modified by pasture treatment, the greatest increase being obtained where the pasture was treated with both lime and soluble phosphate. The pasture thus treated maintained $3\frac{1}{2}$ times the live weight as compared with the control.

The Merino sheep does not produce the same quantity of wool per head when grazed in the south-east of South Australia as when grazing on the Adelaide plains. No significant differences in wool quality were observed with the various pasture treatments.

(iv) *Effect of Frequency of Cutting on the Productivity and Botanical and Chemical Composition of Natural Pasture.*

The results of this investigation have been recorded by Messrs. Davies and Sim.*

The highest yield of dry matter was obtained from natural pasture by allowing the herbage to reach maturity. More frequent cutting tended to reduce the yield, and fortnightly cutting seriously depressed the yield. Pasture cut three times during the season yielded approximately 94 per cent. of the yield obtained from one cut, and produced herbage of higher nutritive value and lower fibre content than mature herbage. The highest production of crude protein was obtained from pasture cut at two to four-weekly intervals, the higher protein content of the young herbage more than counterbalancing the depressed yield.

(v) *Pasture Management Investigations.*

An area of exceedingly rich soil under irrigated sown pasture was selected at Woods Point, on the River Murray, 60 miles from Adelaide, and used to investigate the effect of varying systems of pasture management on the yield, botanical and chemical composition of the pasture, and the yield of nutrients under systems of grazing and mowing treatments and fertilizing with phosphates, lime, nitrogen, and potash.

Investigations are also being conducted to determine the productivity and persistence of species, strains, and mixtures of species.

The results of the investigation showed that a relatively simple mixture of selected strains of perennial rye grass, cocksfoot, and white clover was highly productive under rotational grazing by sheep. Monthly cuts of such a pasture grazed by sheep on a 28-day rotation gave a total yield of 8.7 tons of dry matter per acre during the season following its establishment, and averaged over 25 per cent. protein and 1 per cent. phosphoric acid.

The yield of pasture under a system of rotational grazing by sheep at intervals of 28 days was found to be considerably higher than that recorded under a system of mowing at 28-day intervals. The yield under grazing was found to be 30 per cent. higher than under mowing treatment. This marked difference in the yield is attributed mainly to the substantial return in nutrients in the form of animal excrements to the pasture under grazing treatment.

It was found that under a system of rotational grazing, a better balance was maintained between the permanent gramineous and leguminous components than under a system of mowing. Under mowing, the pasture changed rapidly from a rye grass dominant to a clover dominant pasture.

Permanent pastures mown at 56-day intervals throughout the year gave 31 per cent. higher yields than the sum of the yields from similar pasture mown at 28-day intervals. Lengthening the growth period of

* Council for Scientific and Industrial Research, Pamphlet 18 (1931).

the pasture not only gave higher yields, but the nutritive ratio of the feed was better suited for fattening sheep than the narrow nutritive ratio of feed obtained under a system of monthly cuts.

The stock-carrying capacity of 70 acres of permanent pasture grazed by sheep was recorded. The pasture carried stock at the rate of 5,924 sheep days per acre. The mean number of sheep carried throughout the twelve months was 16.2 sheep per acre.

(vi) *Growth of Pasture Plants on Mineral Deficient Soils.*

Preliminary studies have been made of the growth of pasture plants under controlled conditions with soils from typical mineral deficient areas in Australasia. Quantities of soil from these areas have been brought to the Waite Institute and used for pot cultures with Wimmera rye grass. Among the soils included in this investigation are the "bush sick" soil of New Zealand, supplied by Mr. B. C. Aston, of the New Zealand Department of Agriculture, the so-called "coasty" soils of King Island (Tasmania) and Kangaroo Island (South Australia), the phosphate deficient soils of Cudgee (Victoria) and Kybybolite (South Australia), and the manganese deficient soil from Yorke Peninsula (South Australia). During 1931, Wimmera rye grass was grown on all these soils, with and without dressings of phosphorus, iron, manganese, &c. The chemical work has not yet been completed.

(vii) *Pasture Survey of Mineral Deficient Areas.*

As opportunity offers, pasture samples are being collected from various parts of Australia where mineral deficiencies are alleged to exist. In course of time these analyses will show the range of variation in mineral composition of given species of pasture plants grown under widely dissimilar soil and climatic regions throughout Australia.

To interpret such analyses correctly, it is necessary to know the composition of a wide range of pasture species grown in a known or controlled environment. It is also essential to compare the pasture plants at fixed stages in their vegetative growth because of the known variability in mineral and protein content as growth advances towards maturity.

Twenty pasture species commonly used for grazing in various parts of Australia have been grown under controlled conditions in pot cultures, and harvested at fixed growth stages. The material is being subjected to complete analysis with a view to determining the range in composition of each pasture species under identical soil and climatic conditions. The chemical work on this section has not yet been completed.

(viii) *Pasture Technique.*

Hitherto, little scientific work has been carried out in Australia on indigenous and seeded pastures. Consequently, much attention had necessarily to be given to the working out of a satisfactory technique for the investigation of grasslands. Satisfactory methods have been developed to measure the productivity, grazing value, and botanical composition of indigenous and sown pastures under grazing conditions. The methods developed are described in the various papers submitted in the progress reports. A paper by Dr. J. Griffiths Davies on "The Experimental Error of the Yield of Small Plots of Natural Pasture" has been published as Bulletin No. 48 of the Council for Scientific and Industrial Research.

3. Factors affecting the Mineral Content of Pastures.

(1) The investigations on the factors affecting the mineral content of pastures, as outlined in the original memorandum to the Empire Marketing Board, have been completed and published as Bulletin No. 49 of the Council for Scientific and Industrial Research by Messrs. Richardson, Trumble, and Shapter. The effect of species, growth stage of the pasture plant, influence of soil type, fertilizers, and soil moisture content on the composition of the pasture are discussed in detail in the Bulletin.

(2) Investigations were undertaken to determine, under controlled conditions, the effect of growth stage and intensities of cutting on the yield and mineral content of the herbage, basal internodes, and root system of a perennial grass—*Phalaris tuberosa*. The results are recorded in a paper by Messrs. Richardson, Trumble, and Shapter. Growth stage was found to exercise a determining influence on the composition of *Phalaris tuberosa*, especially on the protein, crude fibre, and mineral content.

A downward migration of nitrogen and phosphoric acid was found to occur in this plant from the herbage to the basal internodes and root system. It was found that, during the final stages of growth, potash was lost to the soil in considerable quantities from the herbage, basal internodes, and roots.

The yields of all portions of the plant were found to be reduced considerably by increasing the severity of cutting. Notwithstanding a marked decrease in dry matter, consequent on increased cutting, there was a substantial increase in the yield of protein. Taking into consideration the yield of dry matter, yield of nutrients, and the permanence of the plant in a semi-arid environment, three cuttings or grazings each season would probably give optimum results.

4. The Water Requirements of Pasture Plants in Relation to Mineral Assimilation.

The third section of the work referred to in the original memorandum to the Board was the investigation of the water economy of pasture plants in relation to mineral assimilation. A report on this section has been submitted by Messrs. Richardson and Trumble; it gives detailed results of the water requirements of twenty species of pasture plants, and the effect of environment, species, stage of growth, fertilizers, and soil type on the transpiration ratio of typical pasture plants. The factors affecting the water requirement of pasture plants are of significance to all pastoral regions in the arid and semi-arid portions of the Empire, owing to the fact that rainfall is the main factor which limits production from pastures.

5. Extension of Scope of Original Investigations.

In the progress report of the 27th July, 1929, printed as Pamphlet No. 17 of the Council for Scientific and Industrial Research, it was pointed out that the natural grass land associations found in any locality or on any given area are a reflex of the environment, expressed in terms of climate, soil composition, and pasture management, under which the pasture is grown. Moreover, these grassland associations may be profoundly altered in botanical and chemical composition and

the yield of minerals by the introduction of new pasture plants in the sward, by the use of fertilizers, and by varying the character of the pasture management.

(i) *Pure Species and Pasture Management Investigations.*

The investigations show definitely that while the environment exerts an important influence on the mineral content of each plant species, there is a limit to the ability of plants to make use of available mineral nutrients, a limit imposed by the nature of the species itself. Moreover, differential ability to absorb mineral nutrients from non-water-soluble sources has been demonstrated among pasture plants.*

Pure species investigations in relation to the mineral deficiency problem are important, therefore, because of the possibility of establishing, by proper selection of species and by pasture management, a minerally balanced pasture. Evidence is furnished to show that the productivity and carrying capacity of natural pastures in the winter rainfall area of Australia are strictly limited, even in regions of moderate to good rainfall, more especially where phosphates are lacking.

It is also shown that the most economic method of overcoming the mineral deficiency problem on arable land, in regions of moderate to good rainfall, is to replace the "natural" pasture with perennial species adapted to the soil and climate, and to maintain their productivity by appropriate methods of pasture management. In regions of heavy rainfall (over 30 inches), the pasture species commonly used in Britain and New Zealand are of special value, except in the summer rainfall zone.

Investigations at the Waite Institute have shown that the replacement of indigenous perennial species by exotic annuals is accelerated by top-dressing with soluble phosphate. The resultant pasture, composed mainly of annual species, has a restricted period of growth, involving negligible autumn and poor winter production, followed by excessive development in spring, with ultimately a heavy loss of seed and a markedly reduced carrying capacity in the autumn. Messrs. Trumble and Davies, in a paper entitled "The Role of Pasture Species in Regions of Winter Rainfall and Summer Drought," have shown that the most serious drawback of the annual species is the lack of control. The botanical composition is almost entirely dependent upon the annual seasonal conditions. Methods of improvement must necessarily incorporate a large measure of control over the constituent species, otherwise improvement cannot be maintained for successive seasons.

Top-dressing with fertilizers, harrowing, and grazing by stock are too weak an influence on annual species to counteract the variations in climatic forces met with.

Preliminary investigations by the Waite Institute at eight centres in the winter rainfall zone have shown that a number of perennial species are capable of withstanding summer drought in a dormant vegetative condition. Selected strains of *Danthonia*, *Phalaris tuberosa*, perennial veldt grass (*Erharta calycina*), and certain strains of perennial rye grass, lucerne, and various species of *Atriplex* have been demonstrated to persist and yield more abundantly than the "natural" pasture under the climatic conditions of Adelaide, which may be

* Council for Scientific and Industrial Research, Bulletin 49 (1931).

regarded as representative of a wide area of moderate rainfall country (20 inches) in the winter rainfall region. These perennials have the advantage of stability due to perennial root occupation, which prevents opening up of the pasture and entrance of undesirable weeds. They are more amenable to control, are capable of providing herbage over a more extended period of the year than annual species, and they respond to summer and autumn rainfall. Furthermore, with the possible exception of *Danthonia*, they are higher fertility demanders than the annual species, and respond to cultivation and fertilizers better than the annual species.

Two annual species are of special importance and significance in the winter rainfall region, the so-called "Wimmera rye grass"—*Lolium subulatum*—and subterranean clover. Special strains of these are being developed by the Victorian Department of Agriculture, and these, with the perennial species referred to above, are likely to meet the special needs for pasture establishment in the areas of moderate rainfall.

For the reasons outlined above, work on pure species and investigations on pasture management in representative areas of the winter rainfall zone have been regarded as a necessary part of the mineral deficiency investigations, since the whole of the evidence accumulated tends to show that ultimately the most economic method of overcoming mineral deficiencies in pastures in regions of moderate to good rainfall (and these support the greater portion of the stock population of Australia) is to replace the "natural" pasture with suitable species, or mixtures of pure species, adapted to the environment and to maintain the pasture at a high level of productivity and nutrient value by fertilizers and pasture management.

(ii) *Physiological Aspects of Mineral Metabolism.*

A further extension of the scope of the investigation has been the development of the physiological aspects of mineral metabolism. The work in this field has been designed to supplement the work already done by fundamental studies on the mineral metabolism of pasture plants.

It is hoped by such investigations to throw further light on the principles underlying the phenomena with which the work surveyed above has been concerned in a more immediately practical way.

The work was commenced in July, 1931, when Dr. A. H. K. Petrie, M.Sc., Ph.D. (Cantab.), was appointed as a plant physiologist to investigate the physiological aspects of mineral deficiency problems.

Two progress reports give details of the nature of the work projected. The aim of the investigations in progress is the study of the external and internal factors governing the intake of mineral ions, and the part played by these ions in regulating the metabolism, growth, and development of the plant. Two studies on these lines are already in progress.

The first concerns the relation of mineral ions to transpiration. A study of the effect of various manurial treatments on the transpiration ratio of *Atriplex* has been made, and is described in a progress report. The outcome of this and other investigations has been to show that certain ions, namely, nitrate and phosphate, reduce the transpiration

ratio to a marked extent. A scheme of work projected for the present year is designed to contribute to the physiological explanation of this reduction.

The second of these studies has been designed to investigate the energy relationships of ion intake. Experimental work is being carried out to discover to what extent the energy made available in respiration is utilized by the plant in the process of accumulating mineral ions within its tissues. If it can be shown that the accumulation of mineral substances in the plant is largely governed by the amount of energy made available in respiration, we shall have a clearer knowledge of the mineral metabolism of the plant as a whole.

6. Investigations on Manganese Deficiency in Soils.

The investigation of manganese deficiency in soils has been intensively studied by the Agricultural Chemistry Division of the Waite Institute. These investigations were carried out in the first instance by Messrs. Samuel and Piper, who demonstrated that three areas in South Australia suffered from manganese deficiency. These are—

- (i) a rich brown volcanic ash soil from round Mounts Gambier and Schank;
- (ii) a black clay humus reclaimed swamp soil from Penola; and
- (iii) a light calcareous soil from Yorke Peninsula, Kangaroo Island, and Eyre Peninsula.

By means of water cultures and the use of specially prepared manganese-free ferric citrate, they were able to demonstrate that manganese was an essential element for plant growth, and that if manganese is withheld from the plant, the so-called "grey speck" or manganese deficiency disease developed.

The results of these investigations are recorded in the *Annals of Applied Biology*, November, 1929.

C. S. Piper (*Journal of Agricultural Science*, 1931) showed that the oxidation reduction equilibrium of the soil had an important bearing on the availability of manganese to plants, that normal growth on manganese deficient areas could be established by subjecting the soil to reducing conditions such as those brought about by high saturation or temporary waterlogging, and that the responses obtained by either of these treatments were similar in every respect to those obtained by the application of manganese sulphate to the soil.

The application of small quantities of manganese sulphate (14-28 lb. per acre) has been demonstrated to be commercially profitable on the soil types referred to above, and to result in a great increase in production (Scott: *Journal of Agriculture, South Australia*, March, 1932).

The work on manganese deficiency in soils has been an independent collaborative investigation by the Chemical and Plant Pathological Departments of the Waite Institute, undertaken in the first instance at the request of the Department of Agriculture of South Australia in 1925, which sought information on the cause of the poor growth of oats on certain soil types in South Australia.

A study of the problem led to the discovery of a number of areas in South Australia deficient in available manganese, the necessity for manganese for plant nutrition, the conditions under which manganese could become available in the soil, and the establishment of economic methods of correcting the deficiency.

7. List of Reports on the Mineral Content of Pastures.

A classified list of reports of the various sections of the investigation is submitted herewith:—

A. FIELD INVESTIGATIONS—INVESTIGATIONS ON NATURAL PASTURES.

- (1) "Investigations on the Mineral Content of Pastures"—J. G. Davies, B.Sc., Ph.D., A. E. Scott, M.Sc., and K. M. Fraser, B.Agr.Sc.
- (2) "The Effect of Topdressing with Artificial Fertilizers on the Yield, Botanical Composition, and Carrying Capacity of a Natural Pasture"—H. C. Trumble, M.Agr.Sc., and K. M. Fraser, B.Agr.Sc.
- (3) "The Effect of Superphosphate on Natural Pasture in a Phosphate Deficient Region"—J. G. Davies, B.Sc., Ph.D., and A. E. Scott, M.Sc.
- (4) "The Mineral Content of Pastures"—A. E. V. Richardson, M.A., D.Sc. Published as Pamphlet No. 17, C.S.I.R.
- (5) "The Influence of Frequency of Cutting on Natural Pasture in Southern Australia"—J. G. Davies, B.Sc., Ph.D., and A. H. Sim, B.Sc., B.Agr.Sc. Published as Pamphlet No. 18, C.S.I.R.
- (6) "The Experimental Error of the Yield from Small Plots of Natural Pasture"—J. G. Davies, B.Sc., Ph.D. Published as Bulletin No. 48, C.S.I.R.
- (7) "Composition of Pasture Species from various Regions of Australia"—A. E. Scott, M.Sc.

SOWN PASTURES AND PASTURE MANAGEMENT INVESTIGATION.

Species and Strain.

- (8) "The Role of Pasture Species in Regions of Winter Rainfall and Summer Drought"—H. C. Trumble, M.Agr.Sc., and J. G. Davies, B.Sc., Ph.D. *Jour. Coun. Sci. Ind. Res.*, 4: 140, 1931.
- (9) "The Taxonomic and Agricultural Characters of the *Danthonia* Group"—A. B. Cashmore, B.Sc., Research Student, C.S.I.R.
- (10) "Comparison of *Lolium perenne* and *Phalaris tuberosa* at varying Stages of Growth"—A. B. Cashmore, B.Sc., Research Student, C.S.I.R.
- (11) "The Improvement of *Phalaris* Species by Selective Breeding"—H. C. Trumble, M.Agr.Sc.
- (12) "Preliminary Investigation of Indigenous Saltbushes (*Atriplex*) in an Area of Winter Rainfall and Summer Drought"—H. C. Trumble, M.Agr.Sc.
- (13) "The Nitrogen and Phosphoric Acid Content of Twenty Species of Pasture Plants at Fixed Growth Stages"—R. E. Shapter, A.A.I.C.

Pasture Management.

- (14) "Seasonal Productivity and Botanical Composition of Irrigated Sown Pastures under varying Systems of Pasture Management"—A. E. V. Richardson, M.A., D.Sc.
- (15) "The Protein and Phosphoric Acid Content of Sown Pasture subjected to varying Systems of Pasture Management"—H. P. C. Gallus, B.Sc.

B. FACTORS AFFECTING THE MINERAL COMPOSITION OF PASTURES.

- (16) "Factors affecting the Mineral Content of Pastures with Particular Reference to the Environmental Conditions incidental to Southern Australia"—A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc., and R. E. Shapter, A.A.I.C. Published as Bulletin No. 49, C.S.I.R.
- (17) "The Effect of Growth Stage and Intensities of Cutting on the Yield and Composition of a Perennial Grass—*Phalaris tuberosa*"—A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc., and R. E. Shapter, A.A.I.C.

C. THE WATER REQUIREMENTS OF PASTURE PLANTS.

- (18) "The Transpiration Ratio of Farm Crops and Pasture Plants in the Adelaide District"—A. E. V. Richardson, M.A., D.Sc., and H. C. Trumble, M.Agr.Sc. *Jour. of Agric., S. Aust.*, 32: 224, 1928.
- (19) "The Water Requirements of Pasture Plants in a region of Winter Rainfall and Summer Drought and the Factors affecting the Transpiration Efficiency"—A. E. V. Richardson, M.A., D.Sc., and H. C. Trumble, M.Agr.Sc.
- (20) "The Relation of Mineral Ions to Transpiration"—A. H. K. Petrie, M.Sc., Ph.D.

D. GENERAL.

- (21) "The Rate of Growth of a South Australian Merino Fleece"—K. M. Fraser, B.Agr.Sc. *Jour. Coun. Sci. Ind. Res.*, 4: 204, 1931.
- (22) "The Relation of Ion Intake to Respiration in the Plant"—A. H. K. Petrie, M.Sc., Ph.D.
- (23) "Manganese as an Essential Element in Plant Growth"—G. Samuel, M.Sc., and C. S. Piper, M.Sc. *Annals of Botany*, 16: 493, 1929.
- (24) "The Availability of Manganese in the Soil"—C. S. Piper, M.Sc. *Jour. Agric. Sci.*, 21: 762, 1931.

8. Conclusion.

From the foregoing account and the appended reports and illustrations, it will be seen that a number of promising lines of work on grassland problems justifying further investigation have been opened up

The usual difficulties incidental to research work in a comparatively new field were encountered in the early stages of the investigation, and a technique adapted to the various phases of research had to be worked out.

Early progress was somewhat delayed by want of laboratories and essential equipment. These difficulties have been surmounted, and progress in all branches of the investigation should be more rapid.

The results of intensive study of grassland problems in Australia should be of general interest to workers in other portions of the Empire, and in particular to workers in regions in which rainfall is a limiting factor to pasture production.

It is a pleasure to place on record the zeal with which the various members of the team of workers engaged on mineral deficiency problems have co-operated to promote the interests of the investigation.

Preliminary Investigations on the Cultivation of Indigenous Saltbushes (*Atriplex* spp.) in an Area of Winter Rainfall and Summer Drought.

By H. C. Trumble, M.Agr.Sc.

(Waite Agricultural Research Institute.)

The brief article that follows is one of the reports (No. 12) that have been made in connexion with the co-operative investigations into the mineral deficiencies of pastures which are mentioned by Professor Richardson elsewhere (see page 150).—ED.

I. Introduction.

The saltbushes have long been regarded as the principal forage plants of arid Australia. Over extensive areas of the interior, the rainfall is too low in quantity and too uncertain in distribution to support species that are not capable of withstanding severe drought. The flora of these areas consists of an open woodland of low trees with an undergrowth of shrubs, together with ephemeral grass and herbage following heavy rains (1). The ephemeral species provide a "flush" in good seasons, but are of little value during prolonged drought. On the other hand, the bushy undershrubs of *Atriplex*, *Kochia*, and *Rhagodia* persist vegetatively, and provide forage under intense climatic conditions.

The Australian species commonly classed as saltbushes are 137 in number, and are arranged under 15 genera (2). All of these belong to the botanical order Chenopodiaceae.

The most valuable species in the pastoral areas are the true saltbushes (*Atriplex* spp.) of which there are 30 in Australia. The majority of these are perennials. Seven species have been cultivated under experimental conditions at the Waite Institute in connexion with investigations of the mineral content of pastures.

In South Australia, the true saltbushes are not frequently found in the winter rainfall zone receiving more than 15 inches per annum. The possibility exists, however, of growing them as summer pastures in the widespread areas of liberal winter rainfall and intense summer drought. In these areas, the period of lowest production is from February to May, immediately prior to the first winter rains, and an improvement in the quality and quantity of the herbage available during this period would be of greater value than a similar improvement at any other time of the year.

Lucerne has been fairly extensively cultivated in this type of environment for the provision of forage during the drought period. A deeply penetrating root system enables this species to withstand extreme drought, but the leaves and stems are typically mesophytic in structure, and the water requirement is high in comparison with other cultivated plants (3), indicating low productivity where the soil moisture supply is limited.

In contrast with lucerne, the saltbush species are characterized by modifications of the leaf structure (4), which are thought to be of value in the restriction of transpirational activity. These plants are

included in the group of tomentose microphylls (5), to which also belong the sagebrushes (*Artemisia* spp.) of North America and North Africa, and the karroo bush (*Pentzia incana*) of the South African Karroo. The majority of the species normally possess small leaves, the surfaces of which are covered with a dense tomentum of vesicular hairs, and in addition, the leaves of some species are capable of absorbing moisture directly from the atmosphere (6). The principal genera of the group—*Atriplex*, *Kochia*, *Rhagodia*, *Artemisia*, and *Pentzia*—are important sources of permanent forage, and enable stability to be achieved in the production of livestock in arid regions.

In discussing the conditions under which saltbush communities grow, Osborn and Wood (8) show that increasing dominance is correlated with increasing aridity. Whilst having attained a remarkable degree of xerophytism, however, they are not necessarily halophytic, despite the high concentration of salt normally found in their leaves. In fact, the zonation of certain *Atriplex* species in South Australia coincides with decreasing salinity of the soil (7), and typical saltbush communities may develop on soils of ordinary salt concentration.

It has been shown (9) that the mature herbage available for stock during the late summer and early autumn in areas of winter rainfall is liable to marked deficiencies of protein and phosphoric acid, and that both *Atriplex semibaccatum* and *A. vesicarium* are characterized by a high content of these nutrients. It is probable, therefore, that saltbush paddocks for summer forage would prove valuable adjuncts to the winter pastures in summer drought areas.

2. The Cultivation of Saltbushes.

The cultivation of saltbushes, like that of the native grasses, is not carried out commercially in Australia. A number of species were introduced into the United States towards the end of the 19th century, however, and of these *Atriplex semibaccatum*, known as Australian saltbush, has been cultivated with success in California, Arizona, and New Mexico (10). Where planted in other portions of the United States, it has proved a failure, and its present distribution is confined to areas receiving a mean annual rainfall of 9 to 20 inches, with a winter incidence. While the present use of this species has fallen short of early expectations, its introduction has proved beneficial to those areas where it has become naturalized.

Some experimental work with saltbushes has been carried out by the Department of Agriculture in New South Wales, and Breakwell (11) states that the plants readily respond to cultivation.

In trials carried out at the Waite Institute with some 300 species of forage plants during the last five years, several species of *Atriplex* have demonstrated a capacity for vigorous development under conditions of limited rainfall during the summer-autumn period of shortage. Of seven indigenous species grown, *Atriplex semibaccatum* has received particular investigation because of its suitability for grazing conditions.

3. Seed Germination and Early Establishment.

The effects of varying temperature and moisture content of the soil on the germination of *Atriplex semibaccatum* have been investigated in the laboratory in order to throw light on the factors affecting establishment in the field.

A multiple temperature incubator of fourteen compartments, with a temperature range of 0 to 40° C., was employed to determine the percentage germination and germination rate at different temperatures. The mean temperature for each compartment is given in Table I. Petri dishes 9 cm. in diameter were each provided with 50 gms. of sterilized quartz sand, maintained subsequently at 50 per cent. of its water-holding capacity, in which 100 seeds of *Atriplex semibaccatum* were sown. Each test was carried out in duplicate, and an incubation period of 21 days was allowed.

The following table summarizes the results obtained, and these are graphically expressed in the graph on page 155.

TABLE I.—Showing Percentage Germination of *Atriplex semibaccatum* at 7 and 21 Days, and Number of Days Taken to Reach 15 and 50 per cent. Germination at Different Temperatures.

Mean Temperature °C.	5.0	8.0	10.5	12.5	14.5	16.0	17.5	20.0	21.0	23.5	25.5	29.0	32.5	37.5
PERCENTAGE GERMINATION.														
7 days ..		5	22	37	48	53	46	39	30	12	8	3	8	..
21 days ..	36	56	68	70	73	68	65	61	65	31	18	18	19	..
DAYS TO REACH 15 AND 50 PER CENT. GERMINATION.														
15 per cent. .	16	9	7	6	5	5	5	5	6	8	11	11	13	..
50 per cent. .	.	17	10	8	8	7	8	13	12	.	..	..	..	..

The optimum temperature for the germination of *Atriplex semibaccatum* is in the vicinity of 16° C., with an optimum range of 10 to 22° C., and the species is thus adapted to winter germination, despite the summer incidence of its growth. This conclusion is supported by field trials in which winter sowing has resulted in satisfactory establishment.

The effect of moisture content was separately investigated, using the same technique. Petri dishes in duplicate were maintained at moisture saturations varying from 10 per cent. to 100 per cent. saturation of sand with water. The results are given in Table II.

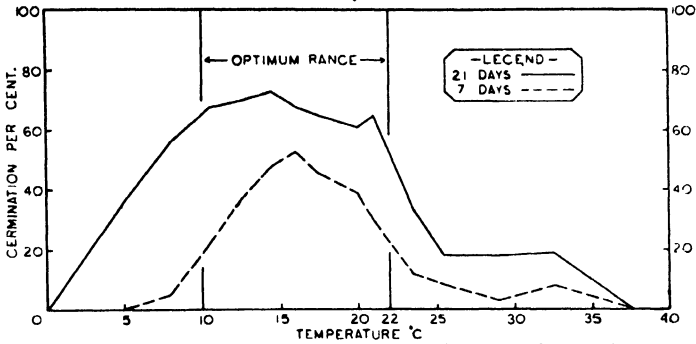
TABLE II.—Showing Percentage Germination of *Atriplex semibaccatum* at 7 and 21 Days, and the Number of Days Taken to Reach 15 and 50 per cent. Germination, at Different Moisture Saturations.

Percentage Saturation with Moisture	10	20	30	40	50	60	70	80	90	100
PERCENTAGE GERMINATION.										
7 days ..	1	9	38	47	58	54	64	54	33	..
21 days ..	1	33	65	69	67	69	78	73	47	9
DAYS TO REACH 15 AND 50 PER CENT. GERMINATION.										
15 per cent.	..	12	5	4	4	4	4	4	4	..
50 per cent.	..	..	9	8	6	7	6	7	..	..

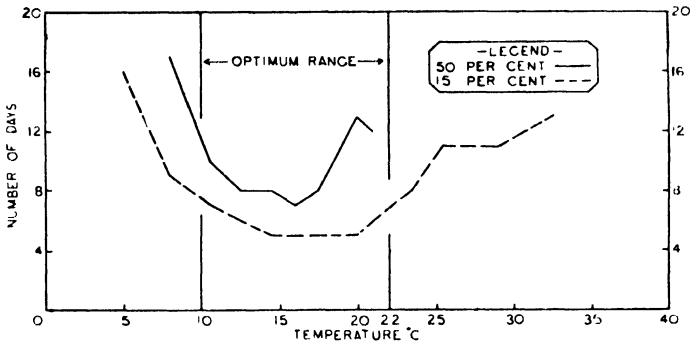
The results of this test indicate that *Atriplex semibaccatum* will germinate over a wide range of moisture content, but that optimum germination occurs under fairly wet conditions, i.e., at about 70 per cent.

saturation. It is of interest to note that even at full saturation, 9 per cent. germination occurred. This provides further evidence for the desirability of sowing in winter, before the surface soil becomes dry as a result of hot weather in early spring.

THE EFFECT OF TEMPERATURE ON THE GERMINATION OF TRAILING SALTBUSH (*ATRIPLEX SEMIBACCATUM*)



1. PERCENTAGE GERMINATION AT 7, AND 21 DAYS.



2. DAYS TAKEN TO REACH 15, AND 50 PER CENT GERMINATION

4. Preliminary Observations under Field Conditions.

Atriplex semibaccatum and *A. halimoides* were established in the field at the Waite Institute for the first time in July, 1929. The seeds were germinated in seed boxes in winter and transplanted to small plots in the field during early spring. Vigorous development occurred with both species, following a thunderstorm on 28th December. Towards the end of autumn in 1930, the herbage (see Plate 1, Fig. 1) was harvested, and the produce dried, weighed, and subjected to an analysis for proportion of leaf present. The following results were obtained:—

TABLE III.—Production per Acre of Two Saltbush Species, Including Production of Leaf, under Field Conditions, Waite Institute, 1929-1930 Summer.

Species.	Dry Matter per Acre (Tons).	Percentage Leaf.	Dry Leaf Produced per Acre (Tons).	Rainfall (Inches)		
				Winter preceding Growth (June–Oct.).	During Growth (Nov.–May).	Total.
<i>Atriplex semibaccatum</i>	4.76	%	2.45	13.17	7.37	20.54
<i>A. halimoides</i> ..	2.90	51.5 41.2	1.20			

The root system of a typical plant of *A. semibaccatum* was excavated and traced to a vertical depth of 5 feet through a heavy clay subsoil, and a deep root system has also been found in *A. vesicarium* and *A. halimoides*. (See Plate 1, Fig. 2.) It appears that saltbush is thus capable of utilizing winter rains which penetrate the subsoil before growth has commenced.

Mineral analyses of saltbush (9) indicate that the protein and mineral contents are high. It is evident, therefore, that yields such as those quoted above would remove large quantities of nutrients, particularly nitrogen, phosphoric acid, and sodium chloride.

Subsequent observations in the field demonstrated that the fertility of the soil might readily be lowered by saltbush, and that invasion and competition by winter weeds and herbage during the rainy season, when saltbush is normally dormant, tended to occur. These problems are at present under investigation.

5. Replicated Field Experiments.

In September, 1931, an area of the experimental field was divided into 24 plots of 1-30th acre each. The plots were set out to accommodate six treatments replicated four times, and randomized within four blocks. The treatments were as follows:—

1. Lucerne (control).
2. Trailing saltbush (*Atriplex semibaccatum*).
3. Bladder saltbush (*A. vesicarium*).
4. Dwarf saltbush (*A. halimoides*).
5. Old man saltbush (*A. nummularium*).
6. Angas saltbush (*A. Muelleri*).

Uniform cultivation treatment and a dressing of 2 cwt. superphosphate per acre were applied over the entire area.

Each species was sown with tested seed on 24th September, 1931, at the rate of 20 lb. per acre. Owing to exceptionally wet weather during the winter period, it was not possible to sow in July or August—the months during which most favorable conditions for germination and establishment occur. During September, 4.51 inches were received, but from 1st October to the following March, the total rainfall was only 3.74 inches.

On 18th January, plant counts were made on each plot. Laboratory determinations of seed viability and number of seeds per pound, used in conjunction with the plant counts, enabled the percentage establishment from seed for each species to be calculated, and these data are given in the following table:—

TABLE IV.—Showing Laboratory Germination, Viable Seeds Sown per Plot, and Percentage Establishment from Seed for Lucerne and Five Saltbush Species Sown under Field Conditions, Waite Institute, September, 1931.

Species.	Lb. seed per acre.	Seeds per lb.	Lab. germination.	Viable seeds per lb.	Viable seeds per acre.	Viable seeds per plot.	Plants present Jan. 18th.	Percentage established from seed.
Lucerne	20	199,800	%	158,800	3,117,000	103,900	46,500	%
<i>A. semibaccatum</i>	20	168,000	78	114,000	2,293,000	76,400	3,704	44.75
<i>A. vesicarium</i>	20	87,700	68	36,800	737,000	24,600	88	4.84
<i>A. halimoides</i>	20	135,400	42	33,800	677,000	22,600	2,164	0.36
<i>A. nummularium</i>	20	89,000	25	18,800	376,000	12,500	213	9.58
<i>A. Muelleri</i>	20	648,000	21	168,600	3,370,000	112,300	8,803	1.70
			26					7.84

Each of the saltbush species established poorly in comparison with lucerne. This was probably due to the late sowing, as soil temperatures were considerably higher than the optimum range (10 to 22° C.), whereas the surface soil tended to remain at a relatively low moisture content. Fortunately, sufficient seed had been sown to provide a satisfactory cover of each species, and on 23rd January, two sample cuts of $\frac{1}{2}$ square metre were made at random from each of the plots growing lucerne, *A. semibaccatum*, *A. halimoides*, and *A. Muellieri*. The two remaining species are of shrubby habit, and the individual plants were not sufficiently advanced to permit cutting or grazing. These were allowed to become fully established as shrubs before being grazed.

The plots which were sampled were then grazed individually with sheep until each had been cropped to the level of the sampling. The plots were separated by temporary fencing, and sufficient sheep were employed to graze each thoroughly within a period of two days, the numbers of sheep per plot being adjusted at the end of the first day.

After the completion of grazing, further production of forage occurred on each plot, and on 16th March the plots were again sampled and grazed similarly. The third and final sampling was carried out with all six species, including *Atriplex vesicarium* and *A. nummularium*, on 5th May.

The results, expressed in cwt.s., of air-dry forage produced per acre by each species are given in Table V.

TABLE V.—Showing Air-dry Forage Produced by Lucerne and Saltbush Species on 23rd January, 16th March, and 5th May, 1932.

Species.	Cwts. per Acre.		
	First Grazing (23rd January).	Second Grazing (16th March).	Third Grazing (5th May).
Lucerne	1·80	1·76	9·73
<i>Atriplex semibaccatum</i>	12·27	22·26	12·84
<i>A. halimoides</i>	9·06	9·36	3·70
<i>A. Muellieri</i>	14·67	12·94	8·18
<i>A. vesicarium</i> .. .. .	..	..	6·71
<i>A. nummularium</i> .. .. .	..	..	9·11

The above results indicate that three species of saltbush are capable of producing higher yields of forage than lucerne during the first summer. It is premature, however, to assess their relative values on the results of the first growing season, and further investigation is necessary before the suitability of these plants for permanent or temporary pasture can be properly judged.

A. Muellieri was the most vigorous species from seed, but the yields in this case tended to decrease as the season progressed. *A. halimoides* showed a similar tendency, with yields at a lower level. Both species seeded profusely during February and March. *A. semibaccatum* was outstanding in production and in recovery after grazing, and this species also formed seed abundantly.

Differences in palatability were very obvious. Lucerne was the most palatable species throughout, with *A. Muellieri* the least palatable. Of the remaining saltbushes, *A. semibaccatum* and *A. nummularium* were eaten most readily. All species were thoroughly grazed during January and March, but a comparatively large number of sheep was necessary in the case of *A. Muellieri*.

Of the saltbush species investigated, *A. semibaccatum* appears to be the most promising for grazing conditions in the Adelaide environment.

6. The Water Requirement of Saltbush.

In comparison with other species investigated, the saltbushes are characterized by a low water requirement. *Atriplex semibaccatum* has been found to require considerably less water per unit of dry herbage than lucerne. In addition, the individual yearly values for *A. semibaccatum* show much less variation than those for lucerne as indicated by the standard errors given in Table VI.

The water requirement of lucerne has been determined at the Waite Institute during five seasons, and that of *A. semibaccatum* during four seasons. Unfortunately, both species were grown under similar conditions in three seasons only. The available data are sufficient, however, to demonstrate the higher water requirement of lucerne, as shown in the following table.

TABLE VI.—Showing Water Requirement of *Atriplex semibaccatum* as Compared with Lucerne, Waite Institute, 1925-31.

—	<i>A. semibaccatum</i> , 1926, 28, 30, 31.	Lucerne, 1925-8, 31.	<i>A. semibaccatum</i> , 1926, 28, 31.	Lucerne, 1926, 28, 31.
Transpiration Ratio	365	753	357	759
Standard Error ..	..	.	±15	±119

The results of the 1931 determination, which was carried out during a particularly dry period, are given in Table VII. Both species were sown under identical conditions on 6th November, 1931, and harvested at the flowering stage in January, 1932.

TABLE VII.—Showing Green and Dry Herbage Produced, Water Transpired, Transpiration Ratio and Root Production of Lucerne and *Atriplex semibaccatum* in Pot Cultures, 1931-32 Season, Waite Institute.

Species.	Green weight per pot (gms.).	Dry weight per pot (gms.).	Percentage moisture.	Transpiration (kg.).	Transpiration Ratio.	Dry weight of roots per pot (gms.).
Lucerne ..	55·21	14·89	73·0	14·39	966	5·09
Saltbush ..	144·90	34·67	76·1	12·45	359	4·88

The production of forage was considerably greater in the case of the saltbush, although actually less water was transpired. The slight difference in the weights of the root systems was not significant.

It is thus evident that *Atriplex semibaccatum* is more efficient than lucerne in the utilization of soil moisture, and it may be expected therefore to produce higher yields of forage on limited quantities of rainfall during the summer months.

7. The Effect of Different Nutrients on the Dry Matter Production and Transpiration Ratio of *Atriplex semibaccatum*.

In view of its yielding capacity and high content of nitrogen, phosphorus, sodium, and chlorine, it is to be expected that the demands of saltbush on the supply of nutrients in the soil are considerable. The determination of the reaction of saltbush to fertilisers is therefore of importance.

During 1931, a series of 48 pots was filled with a uniform mixture of Waite Institute soil two parts, and sand one part, and sown with *Atriplex semibaccatum* on 2nd June. The series was divided into eight groups of six pots each, and given fertiliser treatments as follows:—

1. Nil.
2. Superphosphate.
3. Sodium nitrate.
4. Sodium chloride.
5. Super + sodium nitrate.
6. Super + sodium chloride.
7. Super + sodium nitrate + sodium chloride.
8. Super + sodium nitrate + 4 sodium chloride.

Six grams of each nutrient, equivalent to 1,000 lb. per acre and to .03 per cent. of the soil, were applied per pot, except in treatment 8, where 24 grams sodium chloride were applied. The nutrients were thoroughly mixed with the surface soil prior to sowing, and the usual technique employed at the Waite Institute (9) was followed throughout the investigation.

The pots were harvested between 19th November and 4th December, each complete block of eight different treatments being harvested during a single day. Six separate harvesting dates were employed to enable osmotic pressure determinations on the material to be carried out immediately after harvest (12).

The green weight, dry weight, and transpiration ratio for each pot were determined, and the significance of the differences due to treatments assessed by the analysis of variance (13). The variance due to blocks is ascribable partly to the position of the individual blocks within the pot-culture house, and partly to differences in the date of harvest of each block.

The results obtained are summarized in Table VIII.

TABLE VIII.—Showing the Effect of Different Fertiliser Treatments on the Production of Dry Matter, and the Transpiration Ratio of *Atriplex semibaccatum* Grown in Pot Cultures, Waite Institute, 1931.

Treatments.	1 Nil.	2 Super.	3 NaNO ₃	4 NaCl.	5 Super. and NaNO ₃	6 Super. and NaCl.	7 Super. NaNO ₃ and NaCl.	8 Super. NaNO ₃ and 4NaCl.	Mean.	Standard Error.
(a) DRY MATTER PRODUCTION.										
Dry matter per pot (gms.) ..	54.36	51.86	95.29	46.38	91.24	46.34	99.58	75.35	70.05	2.12
Dry matter (per cent.) ..	77.60	74.03	136.03	66.21	130.24	66.15	142.15	107.56	100	3.03
(b) TRANSPIRATION RATIO.										
Transpiration Ratio ..	380	355	302	360	314	351	287	303	29.1	7.80
Transpiration Ratio (per cent.) ..	109.4	107.9	91.8	109.4	95.4	106.7	87.2	92.1	100	2.37

Superphosphate produced no significant difference in either the production of dry matter or the transpiration ratio.

Nitrate of soda significantly and markedly increased the production of dry matter. The increase, which was approximately 75 per cent., is of particular interest, in that a fallowed soil, presumably rich in nitrogen was used. Moreover, the transpiration ratio was significantly decreased by nitrate of soda, to the extent of 16 per cent.

The application of sodium chloride alone resulted in a significant decrease in the production of dry matter, but the transpiration ratio was not significantly altered. A combination of superphosphate and sodium chloride again produced a significant decrease in dry matter production compared with the control, and did not significantly alter the transpiration ratio.

Where sodium chloride was applied at the rate of .03 per cent. of the soil by weight, in conjunction with a basal dressing of superphosphate and nitrate of soda, the yield was increased above that produced by the basal dressing, and the transpiration ratio was lower in this case than with any other treatment.

The increase in dry matter production and the decrease in the transpiration ratio as a result of adding sodium chloride to the dressing of superphosphate and nitrate of soda were both significant.

Where sodium chloride was applied at the rate of .12 per cent. of the soil, however, a dressing equivalent to 1.8 tons per acre, the dry matter production was decreased by 17.4 per cent., and the transpiration ratio was not significantly altered. The plants were similar in general appearance to the plants receiving a smaller dressing of salt.

It is thus evident that the outstanding factor limiting the production of the saltbush under the conditions of this experiment was nitrogen, and that the application of nitrogen as nitrate of soda materially increased the yield and lowered the water requirement. The high requirement of saltbush for nitrogen is further indicated by the results of analyses made on the plant, and by observations in the field.

8. Discussion.

The investigations, so far as they have progressed, have demonstrated that at least five saltbush species may readily be established from seed under field conditions, provided that seeding is effected with due regard to the temperature and moisture conditions of the surface soil.

These saltbush pastures, when established, are of considerable value to livestock in areas subject to summer drought, for the following reasons:—

1. The capacity for production during the period of shortage in late summer and early autumn is high.
2. The water requirement is low, indicating a high efficiency of production in terms of rainfall.
3. The root system is deeply penetrating in nature, and thus capable of utilizing moisture which has reached the subsoil during winter.

4. The protein and phosphoric acid contents are appreciable, and high proportions of sodium and chlorine are also present. Actively growing saltbush, therefore, would probably obviate the necessity for the use of salt and phosphorus licks and of protein concentrates during drought.
5. Under field conditions, three saltbush species produced considerably higher yields than lucerne, the standard summer forage, during the first season.

There are a number of aspects, however, which require further investigation.

Firstly, there is the problem of competition from winter grasses and weeds manifestly suited to the climate. These tend to take possession during winter, when saltbushes are practically dormant, and exert a strong competitive influence on saltbush at the commencement of its growth in spring. This problem calls for investigation to determine the possibilities of exercising control over winter competition.

Secondly, there is evidence that some of the saltbushes are short lived, and this probably applies to *Atriplex Muelleri*, *A. halimoides*, and *A. semibaccatum*, all vigorous during the first summer, but many plants of which die during the second winter. Considerable variation exists within each species, and selection for longevity may be necessary or desirable.

Thirdly, there is the question of fertility maintenance, which may have an important bearing on longevity, and which certainly influences productivity. In this connexion, it has been shown that nitrogen is needed in considerable quantities, but that on the other hand sodium chloride appears to be tolerated rather than required. In respect to the provision of nitrogen, fertiliser experiments under field conditions, and the reaction of saltbush to the inclusion of leguminous plants, present problems for future investigation.

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The Blowfly Problem—Notes on the Effect of Carcass Burial.

By Mary E. Fuller, B.Sc.,

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In the foreword to an earlier article by M. R. Frenay in this *Journal* (Vol. 5, p. 28), the desirability of distinguishing between primary and secondary flies, and of discriminating in control measures against the primary flies has been pointed out.

The investigation of carcass treatment forms a part of the blowfly research of the Division of Economic Entomology. The results obtained indicate that simple burial of a carcass is not only useless from the point of view of controlling blowflies, but actually favours the primary species. The following experiments demonstrate this point.

Experiment 1.

In October, a sheep was killed and cut in halves transversely. The skin and wool were left on, but the viscera were removed. After two days' exposure to flies in the open, one-half was placed in an oil-drum and covered with 2 feet of soil. The other half was left exposed for three more days, lying on the surface of the soil in another oil-drum. The two drums were then brought into the insectary and placed in separate cubicles.

After a fortnight, *Achaetandrus rufifacies** and *Microcalliphora varipes* (both secondary flies) were emerging from the unburied half, and were followed nine days later by *Calliphora stygia*, *C. augur*, and *Lucilia sericata* (all primary). Twelve days after they had been emerging from the unburied half, flies appeared from the buried half. These earlier flies were *C. augur* and the two species of *Lucilia*. Later, when only a few *Peronia* were coming from the unburied portion, *Lucilia*, *C. stygia*, and *C. augur* were still emerging from the buried portion. The period of emergence from the former was 12 days, whilst, from the latter, flies continued to emerge for at least 30 days.

The following table shows the total numbers produced:—

—	Primary Flies.				Percentage of Primary Flies.	Secondary and Tertiary Flies.		
	<i>C. stygia.</i>	<i>C. augur.</i>	<i>L. sericata.</i>	<i>L. cuprina.</i>		<i>A. rufifacies.</i>	<i>M. varipes.</i>	<i>P. rostrata.</i>
Buried..	5,667	1,323	234	16	%	Nil	Nil	Nil
Unburied	816	1,698	35	Nil	100 70	222	189	604

No beetles were produced from the buried half, but after two months 68 *Creophilus* and 30 *Saprinus* emerged from the unburied half. These beetles live on blowfly maggots. Numerous larval *Dermestes* were also present on the unburied half. The total emergence of blowflies from the unburied portion was 3,564, whilst the total from the buried portion was 7,240, more than twice the number.

* This species is commonly known as *Chrysomya rufifacies* Macq.

Experiment 2.

In March, the experiment was repeated, but, because of the cooler weather, the halves were exposed respectively for three and six days. In the October experiment, the hind part of the sheep was buried; in this experiment, the fore part was buried. The whole procedure was the same as before, except that radiators were used to hasten emergence, which otherwise would have been delayed by the cold weather. After a fortnight, *A. rufifacies* and *M. varipes* began to emerge from the unburied half, and ten days later *C. augur* appeared from the buried half. The emergence continued for about five weeks. The following table shows the total numbers:—

—	Primary Flies.				Percentage of Primary Flies.	Secondary and Tertiary Flies.		
	<i>C. stygia.</i>	<i>C. augur.</i>	<i>L. sericata.</i>	<i>L. cuprina.</i>		<i>A. rufifacies.</i>	<i>M. varipes.</i>	<i>P. rostrata.</i>
Buried..	7,667	6,404	158	66	% 100	Nil	Nil	Nil
Unburied	71	12	4	Nil	0.97	167	2,924	5,570

The total number of flies from the unburied half was only 8,448, whilst from the buried half the emergence was 14,295. This experiment demonstrates even more strikingly than the first how burial within the first few days discriminates in favour of the primary flies. The puparia around the unburied half were heavily attacked by *Mormoniella*. Many *C. stygia* puparia were found to be infected with this parasite, which cannot work under the soil.

Experiment 3.

A further experiment was carried out, in which the carcasses were both exposed to blowflies for the same period. In February, two cats were exposed for two days, after which they were brought into the insectary and one was buried. After eleven days, *A. rufifacies* began to emerge from the unburied cat, and seven days later *C. augur* was emerging from both. The total results are shown in the following

—	Primary Flies.		Percentage of Primary Flies.	Secondary Flies.
	<i>C. augur.</i>	<i>L. sericata.</i>		<i>A. rufifacies.</i>
Buried	5,270	106	% 99	29
Unburied	5,443	108	85	1,072

The number of flies that emerged was greater from the unburied than from the buried cat. The correspondence in primaries between the two was very close, and the difference in totals was almost entirely due to the emergence of the secondaries from the unburied cat. *Brachymeria calliphorae* emerged from both carcasses. This parasite attacks the maggots and, unlike *Mormoniella*, works quite readily under the soil.

Experiment 4.

In February, an experiment was carried out to demonstrate whether poisoning combined with burial would prevent maggots from developing. Two cats were exposed for two days. One was then slashed, and a solution of sodium arsenite containing 0.5 per cent. of white arsenic

poured over it. Each cat was then buried in an oil-drum. Flies soon began to emerge from the soil above the unpoisoned cat. Nothing appeared from the other drum, so after three weeks the carcass was dug up. It was partially mummified, and there were no maggots or puparia in it or in the soil, which was carefully examined. The control produced 6,219 *C. augur*, 9 *L. sericata*, and 71 *A. rufifacies*.

Discussion.

The experiments outlined in this paper were set up purely as a demonstration of one practical point which had emerged from the ecological studies of the past three years. The results of Experiments 1 and 2 were almost precisely what one would have expected, if burial were regarded simply as protecting those larvae present in the carcass at the time of burial from competition with those which would have come later. Experiment 3 showed that, in addition to protecting the primary larvae, burial had a deleterious effect on *Achaetandrus rufifacies*. The total effect is to give the primary flies a much greater chance of survival than they would have in an unburied carcass.

In these experiments, the carcasses were covered to a depth of not less than 2 feet with a rather light soil containing stones and clods, well filled in, but not pressed or compacted. This clearly offered no appreciable impediment to the wandering stage maggots of the primary flies. In field studies, the wandering prepupae of *C. stygia* have been observed to travel through at least 10 feet of undisturbed, compact soil in the bank of a creek. In the laboratory, great difficulty is experienced in keeping wandering smooth maggots in containers and even in insectary cubicles. These and other observations indicate that no ordinary compaction of the soil over a buried carcass would materially impede the movements of the wandering smooth maggots, though it might militate against the emergence of adults. In this connexion, it must be remembered that the smooth maggots of the primary flies normally wander well away from the carcass and pupate just under the surface of the ground, whereas the secondary hairy maggots generally pupate on or close to the carcass, a fact which may partly explain the discriminating effect of burial observed in Experiment 3.

Burial of carcasses on a station, where burning is impracticable, may be necessary for sanitary reasons, and it may be suggested that the situation could be met by burial soon after the death of the animal. In warm weather, and particularly in tropical parts of the country, eggs are laid in large numbers on a carcass within an hour or two of death. It is rarely that a carcass is found on a large station before it is at least well supplied with eggs. It has, however, been shown in Experiment 4 that satisfactory results can be obtained by poisoning the carcass before burial. The method used, that recommended originally by W. W. Froggatt, is simple and cheap, and is quite efficient for this particular purpose.

Conclusions.

1. Burial of carcasses favours the primary flies and adversely affects the secondary flies.
2. Ordinary compaction of the soil over a buried carcass will not materially impede the wandering of the full-grown smooth maggots of the primary flies.
3. Poisoning with arsenic before burial is efficient in destroying any maggots present in the carcass.

Investigations on Flag Smut of Wheat.

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Summary.

A short account of the occurrence, distribution, and symptoms of the disease is given, together with the life history of the fungus *Urocystis tritici* Koern which causes the disease.

The methods of inoculation which were found to give best results for glass-house and for field experiments are described.

Manifestation of symptoms and their relation to the degree of infection in different varieties is discussed.

An account of an experiment designed to give a quantitative estimate of the effect of flag smut upon the yield of 40 different varieties is given.

Some interesting aspects of resistance to this disease and the possible correlation of a characteristic of structure or growth of the host with its resistance are outlined.

1. Introduction.

The first official record of the disease flag smut of wheat is to be found in the report of the South Australian Commission on Diseases of Cereals in 1868. There, under the name "black rust," it is reported as a disease with which farmers were familiar, and against which they must protect their crops by certain cultural practices.

This disease now occurs throughout the wheat-growing areas of Australia, and is also to be found in Illinois, Missouri, and Kansas of the United States of America, in South Africa, parts of Japan, in the Punjab region of India, and around Pekin in China. It has also been recorded from Spain, Italy, and Cyprus, and in one case from Transcaucasia in South Russia.

Unlike rust, flag smut has never assumed epidemic proportions, but it takes its steady annual toll of the wheat crop. The loss due to its operation is directly proportional to the acreage of land under cultivation with varieties of wheat which are susceptible to this disease. Noble* estimated that the loss due to flag smut in New South Wales amounted to 2,000,000 bushels, or over 4 per cent. of the total yield.

2. The Disease.

This disease is strictly limited to one host, the wheat plant, and repeated attempts to extend its host range to other cereals and to grasses have failed. Its symptoms are constant in type, but variable in their occurrence and distribution on the plant. The first macroscopic indication of infection is the development of straight, slightly raised, greyish stripes on the leaf or flag and occasionally on the stem. These stripes or sori become dark brown or black as the spores or more accurately spore balls contained within them mature. They run parallel to the veins of the leaf, and may vary from isolated sections of about 1 cm. long to continuous lines along the length of the lamina (see Plate 2, Fig. 1). An infected plant of a "susceptible" variety will either be killed or it may struggle on, its growth rate retarded, its leaves malformed and its tillers terminating in poorly developed, usually

* *Agric. Gaz., N.S.W.*, 38: 385, 1927.

sterile, smutted heads. Reference may be made to Plate 2 to illustrate the difference between a healthy plant (Fig. 3) and a flag-smutted plant (Fig. 2) of the same age of the "susceptible" variety Gluyas.

As the sori mature, they rupture, liberating masses of black spores which, when scattered through the crop, soil, and agricultural implements, form a source of infection for succeeding years. The warm dry period of summer and early autumn in the wheat-growing areas of Australia afford optimum natural conditions for the maturing process of the flag smut spores. According to Verwoerd,* these spores may retain their power of infection in the soil for four years, and when suitable conditions of humidity and temperature occur they will germinate and are capable of re-infecting their host.

Control Measures.—Certain careful cultural practices have been recommended for the control of flag smut, but these are of little use if susceptible varieties are grown repeatedly on one piece of land. Fungicides, such as are usually used against bunt and other smut diseases, do disinfect the seed, but they have no action against the smut which is already lying in the soil, and this latter is by far the greatest source of infection. Further, for obvious practical reasons, it is impossible to devise a system of crop rotations to cover the period of viability of the spores in the soil. Thus the only efficient method of control of this disease lies in the cultivation of suitable varieties of wheat which are immune or highly resistant to flag smut. For this reason, the variety Nabawa, which has both high yielding ability and resistance to flag smut, has become increasingly successful during the past few years.

3. Life History of the Causal Organism.

The fungus *Urocystis tritici* (Koern), which is the organism causing this disease, has so far not been successfully grown on artificial media, and consequently the host plant must form the medium for its investigation. However, its spores can be germinated and grown on artificial media through the earlier stages (promycelial and sporidial) up to the stage of entrance of the germ tube into the coleoptile or young wheat shoot. Each spore or spore ball is not a simple unicellular body, but consists of one to five fertile spore cells surrounded by, and enclosed in, a layer of sterile cells. Each one of the inner fertile cells may germinate and infect the host plant independently.

Entrance of the fungus into the host only occurs through the young entire coleoptile, i.e., before this white sheath has been broken by the first true leaf. Extensive microscopic observations of the process of penetration indicate that the germ tube enters the coleoptiles of "resistant" and "susceptible" varieties alike. In "resistant" varieties, the pathogen is usually not killed, but the subsequent systemic development of its mycelium is inhibited, and its hyphae fail to keep pace with the growth of the host. Its presence, however, is frequently manifest in small smutted shoots which arise from the lower nodes of the main tiller. In the case of susceptible varieties, the growth rate of the fungal hyphae corresponds to that of the meristematic tissues of its host. There is, however, no definite external symptom of infection until the fourth or fifth leaf stage in plants grown

* Union of South Africa. Department of Agriculture, Science Bulletin No. 76, p. 174, 1929.

under artificial conditions, when the characteristic parallel black lines or sori appear along the length of the leaves. This appearance is usually much later in plants grown in the field.

4. Manifestation of Symptoms.

The appearance of the characteristic black lines or sori on the leaves or stem of a wheat plant is the symptom used for diagnosis of this disease. Not only do different varieties react differently to flag smut under similar conditions, but within one variety individual plants will show the disease with different degrees of infection, e.g., in varieties such as Aussie, Canberra, or Federation, an infected plant may be killed at the fourth to sixth leaf stage, or it may survive to produce one or two heads which yield little or no grain. Plants of other varieties, e.g., Bunyip, Geeralying, or Nabawa, may show infection in one or two tillers only, or be quite healthy, while microscopic examination will reveal the fungal hyphae in the base of the plant. Record of this type of infection is lost in the usual infection counts, and the actual effect of the disease can only be estimated by an analysis of yield.

In all observations, it is necessary to distinguish between "whole" or complete infection of a plant and "partial" infection where all tillers do not show symptoms of the disease (see Table 1). In more accurate studies, the individual tillers are identified and classified, and the numbers of infected and healthy tillers of each group are counted. This method gives an expression of the degree of infection.

5. Effect on Yield.

It has been indicated that an analysis of the yield of diseased and healthy plants is the only method by which we can estimate quantitatively the effect of this disease. In order to do this, a randomized paired experiment of treated and untreated rows was sown in 1931 and repeated and extended this year. Forty well-known varieties, namely, Aussie, Bena, Bobin, Bomen, Bunyip, Cadia, Caliph, Canberra, Cedar, Cleveland, Comeback, Currawa, Dundee, Duri, Early Bird, Exquisite, Federation, Firbank, Florence, Ford, Free Gallipoli, Galgalos, Geeralying, Genoa, Gluyas, Gresley, Hard Federation, Major, Marshall's No. 3, Minister, Nabawa, Rancee, Red Rock, Sultan, Sunset, Turvey, Union, Wandilla, Waratah, and Yandilla King, were chosen, and 1,000 seeds of each (500 treated with flag smut inoculum and 500 untreated) were sown. Throughout the growing season observations were made of the number of plants present at various stages, of the time and manner of appearance of the disease, and of heading and flowering dates; and at maturity samples were taken from which can be calculated the yield of healthy, apparently healthy, and diseased plants. This experiment should give not only an estimation of the loss due to flag smut in any one variety, but also an indication of the way in which the disease operates and of the yielding ability of these varieties under the conditions of the experiment.

This year, seed from (1) healthy plants which have not been inoculated with flag smut, from (2) apparently healthy plants which have been inoculated with the disease, but which did not show symptoms of infection, and from (3) diseased plants of ten varieties from the above experiment is being tested for its reaction to flag smut in the field. This test is being made in order to determine whether previous infection of the parent influences the reaction of the offspring to this

disease, for, should this be the case, the farmer who obtains his seed from a diseased area acquires yet another possibility of infection in his crop.

It is popularly believed that early sown crops are more heavily infected with flag smut than late sown crops of the same variety. Actually, the amount of field infection is determined by the susceptibility of the variety under cultivation, the amount of flag smut already in the soil, and the weather conditions over a period from just before sowing until the crop is a few inches high. This year an experiment is being conducted in the field with fortnightly sowings over a period of three months and including eight varieties of different reaction to the disease, namely, Bunyip, Canberra, Cleveland, Early Bird, Galgalos, Geeralying, Nabawa, and Yandilla King. Accurate records of air temperature, humidity, and rainfall are available, and these will be correlated with infection figures for the different planting dates. Thus we may be able to define the climatic conditions favouring infection in the field for a range of "resistant" and "susceptible" early and late maturing varieties.

6. Resistance to the Disease.

It is clear that varieties of wheat differ markedly in their reaction to flag smut. The State Departments of Agriculture, therefore, classify varieties as "immune," "highly resistant," "resistant," "susceptible," or "highly susceptible," according to the infection shown in their field trials. So far, we have not been able to find a variety which is immune to flag smut under all conditions, but there is a promising group of varieties, e.g., Bomen, Bunyip, Cedar, Galgalos, Geeralying, Nabawa, and probably also Dan, Huguenot, Shepherd, Sindi, and Tuela, which can be classified as "resistant." These do not manifest the disease to such a marked degree as do, for example, Canberra, Federation, Aussie, Caliph, Gluyas, Waratah, varieties which can be classified as "susceptible." In making this distinction, not only has the percentage of infection under field and glasshouse conditions been considered, but also the type and degree of infection.

Before any progress could be made in the investigation of the reaction of different wheat varieties and crosses to flag smut, it was necessary to obtain a satisfactory method of inoculation. This was obtained from an extensive preliminary study of the temperature and humidity requirements of the germinating smut spores in relation to those for germination and subsequent development of the host. All possible temperature and humidity combinations were tested against a pre-soaked and a dry inoculum and pre-soaked and dry grain, in order to find the set of conditions best suited to give high infection. Finally, for glasshouse tests where the environment can be controlled, the best results were obtained from the following method. Grain before being planted in a moist seed-bed is soaked for 8 to 12 hours, according to the variety, in a shallow dish of water upon the surface of which smut spore balls have been soaked for about three days at 18° to 23° C. The surface of each grain is covered with a film of smut spores which are on the point of germination when the young wheat plumule and radicle are about to break through the seed coat. No variety or cross so far tested by this method has proved to be wholly and consistently immune to infection. For field experiments

where the environment cannot be controlled, and which involve large populations, the grain is moistened and then covered with a dense coating of smut.

In Table 1, figures are given for glasshouses and field tests in which the grain was inoculated by the methods described above.

TABLE 1.

Variety.	Grown in—	Infection.			Number of Plants.	Percentage Infection.
		Whole.	Partial.	Apparently Healthy.		
Aussie ..	Glasshouse ..	39	7	1	47	98
	Field ..	33	16	11	60	82
Canberra ..	Glasshouse ..	38	8	0	46	100
	Field ..	28	12	32	72	56
Yandilla King	Glasshouse ..	5	24	30	59	49
	Field ..	3	45	29	77	62
Nabawa ..	Glasshouse ..	2	9	54	65	17
	Field ..	1	8	71	80	11
Bunyip ..	Glasshouse ..	1	28	40	69	42
	Field ..	0	14	71	85	16
Geeralyng ..	Glasshouse ..	0	5	41	46	11
	Field ..	0	9	59	68	13

The figures for infection under field conditions are low, but this test was planted under unfavorable conditions for infection. The examples chosen illustrate the reaction of "resistant" and "susceptible" groups of varieties. In the former class, it will be seen that not only are the figures for infection much lower than those of the latter group, but also the numbers of "partial" infections heavily outweigh those for "whole" infections; the reverse is the case for Aussie and Canberra. Yandilla King illustrates an interesting case; the infection figures are high, but the number of partial infections exceeds that of whole infections. Also, in this variety the percentage infection obtained under field conditions consistently exceeds that for glasshouse tests.

To define the reason for the different reactions of wheat varieties to flag smut is the ultimate aim of the investigations under discussion, and it is hoped that, under carefully controlled environmental conditions, the study of the growth relationships of host and pathogen and the tiller relationships within the host will furnish some useful information. Observations have recently been made on the rate of germination and on the total length and rate of growth of the coleoptile in 28 varieties. The data have not yet been analyzed, but a contrast is apparent between the quick germinating varieties with short rapidly elongating coleoptiles (e.g., Galgalos, Nabawa), and the slow germinating varieties with long, slowly elongating coleoptiles (e.g., Canberra, Caliph). Now Galgalos and Nabawa have been classed as "resistant" varieties and Canberra and Caliph as "susceptible" varieties. Should it be possible in this way to correlate some characteristic of structure or growth of a variety with its flag smut reaction, a definite advance in the study of resistance to this disease will have been achieved, and the breeding of strains of wheat even more resistant than those at present known will have been facilitated.

The Keeping Qualities of Dried Grapes as Affected by Processing.

By *W. R. Jewell, M.Sc., A.I.C.,** and *A. V. Lyon, M.Agr.Sc.†*

At a Conference representative of the Australian dried (vine) fruits industry which met in August, 1930, a resolution was carried to the effect that representations be made to C.S.I.R. to have Mr. A. V. Lyon's services made freely available to the dried fruits industry throughout Australia for advisory work in regard to dipping, irrigation, cultural, and packing processes. The Conference re-assembled in November, 1930, and, among other things, approved of suggestions regarding the detailed ways in which effect could be given to the objects behind the resolution. Shortly afterwards, the Dried Fruits Control Board generously granted £1,000 per annum for two years to finance the work involved. So far as packing processes are concerned, it was considered that some investigations into the keeping qualities of dried fruit in relation to the moisture content and in relation to recent innovations in packing house procedure were urgent. In consultation with the State Departments concerned, it was subsequently arranged that the details of this work would be left to the Committee on the Sulphuring of Dried Fruits (see this *Journal* 2: 151, 1929), that Mr. F. de Castella of the Victorian Department of Agriculture would be added to that Committee, that the Committee's functions would be extended to cover the processing of all dried fruits, and that in future it would be known as the Fruit Processing Committee. The present constitution of the Committee is as follows:—A. V. Lyon, Esq., Commonwealth Research Station, Merbein; C. G. Savage, Esq., Department of Agriculture, New South Wales; W. R. Jewell, Esq., Department of Agriculture, Victoria; F. de Castella, Esq., Department of Agriculture, Victoria; and G. Quinn, Esq., Department of Agriculture, South Australia.

The Report that follows gives the results of the above-mentioned co-operative investigations into the keeping qualities of dried vine fruits.—ED.

1. Introduction.

The appearance and general quality of dried grapes may change subsequent to packing. The change almost invariably results in deterioration, taking the form of "sugaring," massing of berries, and darkening. Apart from general depreciation in value, there is also a possibility of a portion of one parcel which was true to type when packed, showing distinctive differences later. For this reason, packers of this dried fruit frequently receive complaints of departure from sample in portion of a parcel originally uniformly graded.

2. Investigations.

(i) *General*.—An investigation was commenced in 1931 to determine whether certain factors could be correlated with any undesirable characteristics that developed subsequently.

The controllable factors considered to affect keeping qualities are:—

- (a) The substances used in the dip prior to drying.
- (b) The moisture content.
- (c) The severity of treatment in the cleaning machines.
- (d) Application of paraffin emulsion.
- (e) Entomological pests.

The investigation took the form of storage trials of fruit that had been subjected to various processing treatments. The fruit was divided into a number of groups, each group excepting one consisting of uniform fruit,

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subjected to different treatment within the group. The unit for treatment was 28 lb. of dried fruit, commercially packed. Some of the groups were chosen as exhibiting, on inspection, apparent differences in moisture content and colour. The storage period extended over approximately twelve months.

The fruit was stored in the offices of the Victorian Department of Agriculture, Melbourne, and for a portion of the time (seven weeks ending 15th August) in a room adjoining the assay furnaces, at a fairly constant temperature of 70° F., which, it was considered, might expedite changes. Initial infestation by dried fruit pests was allowed to develop.

The treatments within the groups and characteristics of the groups are given in Table 1.

(ii) *Treatment*.—The processes indicated in Table 1 are elaborated below :—

(a) *Dipping Practice*.—Similar fruit was treated on the same day by four dips in commercial use, and the resultant dried samples were stored. The examination during storage was especially directed towards colour changes and general quality.

Two of the dips used (the cold dip and the modified temperature caustic dip) have been described elsewhere.* The mixed dip is a later development, evolved at the Commonwealth Research Station, Merbein. The solution in which the grapes are dipped contains 0.5 per cent. potassium carbonate, sufficient caustic soda (approx. 0.5 per cent.) to crack the berries slightly, and 0.4 per cent. (by volume) olive oil. This dip is used at a temperature of 180° F.

The "Ingerson" dip, evolved by Mr. A. C. Ingerson, Berri, South Australia, is a modification of the mixed dip, containing 0.4 per cent. potassium carbonate, 0.4 per cent. caustic soda, and only a very little olive oil (1 part in 4,000). It is used at 190° F.

(b) *The Cleaning Machines*.—Damage by machinery shows in breakage of individual berries. This may effect the free running of the fruit, and also increase crystallization subsequent to packing. On the other hand, it is necessary to remove stems and other extraneous matter from the fruit, and for this reason additional treatment in the machines, known as "cap stemming" since it aims at removal of the stalks of the berries, has been introduced.

(c) *Washing*.—Washing in water is performed in washing machines, and is practised for removal of dust, and small pieces of stalk and such like matter. It is compulsory when fruit is considered unsatisfactory in these respects.

(d) *Application of Paraffin Emulsion*.—The application of a paraffin emulsion to dried fruit came into practice for the purpose of inhibiting infestation by entomological pests of dried fruit. The treatment was devised by Mr. H. F. Showell, Renmark, South Australia, and is covered by patent rights. The efficacy of the treatment (generally known as "Showelling") was investigated by one of us, and a report on this aspect of the treatment is ready for publication. Subsequently, it was noted that the treatment possessed virtues in that it cleaned the fruit and reduced stickiness, thereby promoting free running.

* Council for Scientific and Industrial Research, Australia, Pamphlet 6 (1928)

Varying amounts of paraffin in the Showell solution were included in the treatments for examination of this aspect of the subject and for confirmation, on a commercial scale, of laboratory findings with respect to the effective strength of the solution for control of entomological pests. Two samples in which the paraffin oil had been applied as a spray were also included.

(iii) *Moisture and Sugar Contents.*—Moisture determinations were made three times during the investigation—an initial examination in May; a second examination in August, following a period of warm humid conditions of storage; and a third examination in February, following dry hot summer weather. The percentage of sugar was determined at the commencement of storage. Moisture percentages were determined by the toluol distillation method, and sugar by the Munson and Walker method (direct weighing of cuprous oxide A.O.A.C. 1925). The figures obtained are given in Table 1.

TABLE 1.

Group No.	Box No.	Treatment.	Sugar %.	Moisture % (on dry weight).		
				May, 1931.	Aug., 1931.	Feb., 1932.
I.—Selected for variations in dip	1	Cold dip ..	85.7	17.5	17.4	17.6
	2	Mixed dip ..	..	17.8	19.5	20.2
	3	Ingerson dip ..	..	19.7	18.3	19.5
	4	Modified temperature or caustic soda dip ..	..	20.5	18.3	17.0
II.—Selected for low moisture content	5	Unstemmed ..	..	..	..	..
	6	Graded	85.9	17.2	17.8	18.8
	7	Graded and cap stemmed ..	..	17.5	17.6	..
	8	Water washed ..	..	18.4	19.3	..
	9	7½% " Showell " ..	..	17.6	18.8	..
	10	10% " " ..	..	18.6	20.2	18.8
	11	12½% " " ..	Missing	..	..	..
	12	15% " " ..	..	19.3	19.3	..
	Mean (1-12)	.. ..	..	(18.4)	(18.6)	(18.6)
III.—Selected for average moisture and low sugar	13	Unstemmed ..	..	..	..	..
	14	Graded	82.8	19.6	20.6	19.6
	15	Graded and cap stemmed ..	..	21.4	20.6	..
	16	Water washed ..	..	22.4	21.1	..
	17	7½% " Showell " ..	..	22.5	20.6	..
	18	10% " " ..	..	22.2	20.6	20.0
	19	12½% " " ..	..	19.9	21.1	..
	20	15% " " ..	..	22.4	21.4	..
	Mean (14-20)	.. ..	..	(21.5)	(20.9)	(19.8)
IV.—Selected for average moisture content and average sugar	21	Unstemmed ..	..	..	..	..
	22	Graded	84.5	20.7	22.5	22.1
	23	Graded and cap stemmed ..	..	19.7	21.2	..
	24	Water washed ..	..	22.9	23.5	22.7
	25	7½% " Showell " ..	..	22.1	22.5	..
	26	10% " " ..	..	21.6	23.0	22.7
	27	12½% " " ..	..	22.9	22.5	..
	28	15% " " ..	..	21.9	22.5	..
	Mean (14-28)	.. ..	..	(21.6)	(21.7)	(21.4)

Table 1—continued.

Group No.	Box No.	Treatment.	Sugar %.	Moisture % (on dry weight).		
				May, 1931.	Aug, 1931.	Feb., 1932.
V.—Selected for high moisture and average sugar	29	Unstemmed ..	..	..	..	..
	30	Graded ..	84.4	28.4	28.0	23.5
	31	Graded and cap stemmed	..	24.7	26.1	..
	32	Water washed ..	..	25.2	24.2	..
	33	7½% "Showell" ..	..	25.0	24.2	..
	34	10% " " ..	..	24.7	24.2	22.9
	35	12% " " ..	..	26.2	23.8	..
	36	15% " " ..	..	24.6	22.9	..
	Mean (30-36)	.. ..	..	(25.5)	(24.8)	(23.2)
VI.—Sprayed with paraffin oil	37	.. ..	..	20.7	20.5	18.4
	38	.. ..	..	22.8	22.1	20.2
	Mean (37-38)	.. ..	..	(21.8)	(21.3)	(19.3)
VII.—Selected units for variation in moisture content	39	Low moisture ..	85.3	20.9	20.2	..
	40	Average moisture	87.8	20.8	20.3	18.2
	41	High moisture ..	87.6	21.6	20.0	..
	42	High moisture ..	85.4	21.9	23.9	17.1
	43	Non-irrigated areas	86.1	17.6	17.8	18.4
	44	Non-irrigated areas washed	..	21.6	23.0	19.6
	Mean (39-44)	.. ..	..	(20.7)	(20.9)	(18.3)

Note.—With the exception of Group VII., all the fruit consisted of sultanas Group VII. consisted of currants.

(iv) *Colour.*—The colour of each sample was recorded on a colour chart (Ridgeways). It was found that three colour groups in each box were sufficient to include 98 per cent. of the total fruit. A value for each colour was obtained arbitrarily, by dividing all the colours encountered into five colour groups, and giving a colour unit to each group as under :—

Groups.				Unit colour value.	
Clay colour	5
Tawny olive, Buckthorn brown	4
Antique brown, Sudan brown	3
Brussels brown, Argus brown	2
All darker groups	1

The total colour value of the mixed sample in each box was then obtained by multiplying the percentage in each group by the unit colour value. At an initial examination, samples of all units examined for colour were desiccated and sealed. These samples were utilized as a comparative standard from which colour changes in the stored fruit were observed.

A comparison of the initial total colour values and an indication of the extent of depreciation over the whole period is given in Table 2.

TABLE 2.

Group.	Sample.	Total colour value (May).	Dominant colour.	
			May.	April.
I.—Low moisture	1	44	5-4	4
	2	38	4	3-2
	3	30	3	2
	4	28	3-2	2
II.—Low moisture	5	40	..	..
	6	40	3	2
	7	34	4	3
	8	37	4	3
	9	36	4	3-2
	10	36	4	3
	11	Missing	..	..
	12	36	4	3
IV.—Average moisture	22	26	3	2
	23	27	3	2
	24	28	3	3
	25	25	3-2	2
	26	25	3-2	2
	27	20	2	2
	28	23	3-2	2
V.—High moisture	30	19	2-1	1
	31	22	3-2	2-1
	32	18	2	1
	33	19	2	1
	34	19	3-2	2
	35	19	3-2	2
	36	18	3-2	2
VI.	37	25	3	2
	38	18	2	1

3. Discussion of Results.

(i) *The Effect of the Dip.*—The influence of the dips on colour was most marked and consistent with observations made at the conclusion of field processing. The order of merit in reference to colour was as follows :—

1. Cold dip.
2. Mixed dip.
3. Ingerson dip.
4. Caustic dip.

At the initial examination, the mixed dip approached the colour value of the cold dip, and these two exhibited marked superiority over the remaining two of this series. Subsequently, the mixed dip fruit depreciated, and at the final examination was exhibiting the colour of that of the caustic rather than that of the cold dip. The order of colour value was maintained with loss of colour greatest in the mixed dip. At the conclusion of the trial, the cold dip samples alone could be classed in trade terms as light and bright fruit.

(ii) *The Effects of the Machinery.*—The results of processing in the cleaning machines were apparent in all groups, excepting possibly Group V. Damage to, and breaking of, the individual berries were reflected in crystallization of sugar, massing of the fruit, and stickiness. These characteristics increased fairly regularly with the severity of the treatment, as disclosed by comparisons of the first three samples in each group.

The high moisture content of Group V. may account for sugaring being less in evidence, as these softer berries were probably damaged to a less extent during agitation in the cleaning machines. The work of the cleaning machines is more efficient with dry samples, stalks and "cap stems" being in evidence in the moist fruit of Group V. The "cap stemmed" samples and also the dry samples of Group II. showed to advantage in general cleanliness.

There is thus a conflict of results, in that severe mechanical processing, necessary for cleanliness, may increase sugaring and stickiness, although the fact that well dried samples are relatively easily cleaned affords some relief.

(iii) *Washing in Water.*—The practice of washing dried fruit is limited to samples which cannot be satisfactorily cleaned otherwise. It is recognized that washing reduces general quality, and, in the case of the Zante currant, detracts from the trade value by removal of the "bloom."

Washing inevitably increases the moisture content. Excepting sample 44, the washing was carried out with the minimum effective quantity of water, and analyses disclose increases from 1 to 2 per cent. in moisture content. Sample 43 represents an unwashed control for comparison with sample 44, which was washed in a copious stream, and showed a 5 per cent. increase in moisture content.

It is evident that thorough drying is a necessary provision prior to washing, in order that the added water shall not increase the moisture content unduly. In general, the water-washed samples presented a "soggy," drab-coloured appearance, out of all proportion to the effect that could be attributed to the added moisture percentage. No provision was made for further drying subsequent to washing, and the deterioration in storage may possibly be connected with changes resulting from relatively high moisture content of the integument of the berry when packed. No such deterioration has been noted subsequent to washing during field processing, when further drying is invariably carried out.

(iv) "*Showelling.*"—The examination of the fruit was of a twofold nature, covering both the extent of infestation by pests and also general quality.

The 7½ per cent. emulsion proved inadequate in all particulars, the characteristics of the packed fruit ultimately approaching those of the untreated controls. At a strength of 10 per cent. or over, the Showell treatment markedly increases "free running" of the fruit, and, in comparison with water-washed fruit where comparable amounts of water are added, also preserves colour. At higher strengths (over 10 per cent.) the oil was too much in evidence, coming off freely on the hands when the fruit was touched. The higher strengths were satisfactory in other respects. Larvae of the principal pest of dried fruit (*Plodia interpunctella*) were found at all stages of development on the samples treated with 7½ per cent. Showell solution, though not in such high numbers as in the untreated controls. Fruit treated with 10 per cent. and higher strengths consistently contained only a few adult larvae. Thus, a 7½ per cent. solution may be regarded as ineffective, while 10 per cent. or over is effective. The presence of well-developed larvae on "Showelled" fruit is consistent with former observations and does not indicate ineffective control. Direct application of paraffin proved efficient for pest control (37–38).

(v) *Moisture and Sugar Percentages.*—Determinations of sugar percentages yielded little information, and sugar content has apparently little influence on keeping qualities. The series chosen for low sugar content (13–20) exhibited no special characteristics distinct from other series. Changes in moisture content during storage were insignificant, as shown by the means of the dry (1–12), the medium (14–28), and the wet series (30–36) (Table 1). Moisture percentages showed a close association with definite characteristics. The satisfactory colour associated with a low moisture content (samples 1–12) at the initial examination was in evidence throughout the series, and throughout the period of the trials. There is evidence that deterioration in colour during storage is associated with a high moisture percentage. Much of this effect, however, had taken place prior to the initial examination, which was made some time (4–40 weeks) after packing.

The samples having a high moisture content also had a low colour value at the initial examination, and were inferior to the grade assigned to them when packed. "Massing" and stickiness are undesirable characteristics of all samples with a high moisture content.

(vi) *Colour.*—The arbitrary values assigned to the various treatments (Table 2) show that the initial colour is principally controlled by the dip used in the processing; and that a high moisture content is associated with a low colour value.

Factors affecting colour during field processing have been dealt with in a previous publication.* It is noted that the two principal causes of darkening during field processing (massing by removal from the rack before drying is properly completed, and rain during the drying period) are attributable also to a temporary high moisture content.

4. Summary of Results.

1. The dip used in field processing has a major influence on initial colour value.
2. Sultanas processed by the cold dip, if well dried, retain their colour to a greater extent than fruit processed by mixed or caustic dips.
3. Crystallization of sugar increases according to the severity of the machinery treatment during processing.
4. Crystallization is lessened by a high moisture content, which, however, is undesirable for other reasons.
5. Stickiness and massing are associated with damaged berries and a high moisture content.
6. Washing in water immediately prior to packing decreases general quality, particularly by removal of bloom in the case of Zante currants.
7. A standard of 10 per cent. Showell solution is essential for pest control and to exert a satisfactory influence on the "freedom" of the fruit.
8. High moisture content is associated with deterioration in colour.

5. Acknowledgment.

Acknowledgment is made to Mr. Peter Mallock of the Commonwealth Dried Fruits Board, and to Mr. Plummer, Department of Commerce, for assistance in defining the problem and selecting dried fruit for investigation; and to Mr. D. V. Walters, B.Agr.Sc., Commonwealth Research Station, Merbein, for laboratory and observational work in securing the necessary data during storage.

* Council for Scientific and Industrial Research, Australia, Pamphlet 6 (1928).

A Note on the Relation of Mineral Nutrition to Transpiration in Plants.

By Arthur H. K. Petrie, Ph.D., M.Sc.

(Waite Agricultural Research Institute, University of Adelaide).

The brief article that follows is one of the reports (No. 20) that have been made in connexion with the co-operative investigations into the mineral deficiencies of pastures which are mentioned by Professor Richardson elsewhere. (See page 151).—Ed.

1. Introduction.

The growth of our knowledge of the mineral relations of the plant is bringing increasing realization of the essential part played by inorganic ions in conditioning physiological processes and hence in regulating growth and development. Among such processes is that of transpiration, which may be greatly influenced by the mineral nutrition of the plant. The present note is devoted to a consideration of some observations upon the well-known effect of nitrates in reducing transpiration.

The material used was *Atriplex semibaccatum*, and had been grown as an experiment, described by Trumble (7), to determine the effect of different manurial treatments on production and water requirement; opportunity was subsequently taken, however, to extend the scope of the inquiry to more fundamental physiological considerations.

2. Experimental.

Forty-eight pots were filled with two parts of Waite Institute fallowed loam and one part of Gawler River sand on 14th April, 1931. Eight manurial treatments were applied in six replications on 1st June, being mixed in with the top $\frac{1}{2}$ kgm. of soil; these were as follows in grammes per pot (6 gm. = 1,000 lb. per acre):—

- T1 Nil.
- T2 Superphosphate, 6 gm.
- T3 NaNO_3 , 3 gm. + 3 gm. in August.
- T4 NaCl , 6 gm.
- T5 Superphosphate, 6 gm. + NaNO_3 , 6 gm.
- T6 Superphosphate, 6 gm. + NaCl , 6 gm.
- T7 Superphosphate, 6 gm. + NaNO_3 , 6 gm. + NaCl , 6 gm.
- T8 Superphosphate, 6 gm. + NaNO_3 , 6 gm. + NaCl , 24 gm.
(= 0.12% of soil).

The pots were then sown with *Atriplex semibaccatum*, 5 clumps per pot, on 2nd June. Three kilogrammes of gravel were added to restrict evaporation from the soil. The pots were weighed weekly to determine water loss. The loss from the soil was determined in six fallow pots, and this was subtracted from the total water loss for each pot to give the loss due to transpiration. Water was added weekly to maintain the moisture content of the soil at 58.5 per cent. total saturation.

One replicate was harvested on each of the following dates:—17th, 23rd, 25th, 30th November; 2nd, 4th December. Immediately after harvesting, the fresh weight was determined, and an aliquot removed for estimation of the osmotic pressure of the expressed sap. The sap was expressed under hydraulic pressure of $\frac{1}{2}$ ton, after the

material had been frozen by immersion for several seconds in liquid oxygen*. The osmotic pressure of the sap obtained was determined cryoscopically. The remainder of the material was used for dry weight determination.

The results are given in Table I. In assessing the standard error of each set of data, it was necessary to consider that the harvests were taken on different days. There were thus two factors contributing to the variance among the data in addition to the experimental error: these were treatment and a time factor. The latter was considerable in the case of the osmotic pressure data, since osmotic pressure would be considerably influenced by the varying water-content of the plant. On this account, the process of analysis of variance was applied to each set of data, and the variance due to time and treatment was deducted from the total variance. The standard error given for each set is that obtained from the remainder variance. The details of the analysis in the case of osmotic pressure are given in Table II, and show the high variance due to the time factor.

TABLE I.—PROTOCOL OF EXPERIMENTAL RESULTS
(means of six replications).*

Treatment.				Dry weight.	Net transpiration per pot	Transpiration ratio per pot.	Osmotic pressure.
				gm.	kgm.		atmos.
T1	..	..	..	54·36	19·56	360·0	30·8
T2	..	..	..	51·86	18·35	354·9	31·9
T3	..	..	..	95·29	28·82	302·4	32·4
T4	..	..	..	46·38	16·70	360·6	31·4
T5	..	..	..	91·24	28·61	314·1	34·2
T6	..	..	..	46·34	16·27	351·1	33·9
T7	..	..	..	99·58	28·62	287·4	35·4
T8	..	..	..	75·35	22·67	302·6	36·4
Standard error				±2·12	..	±7·80	±2·66

* Dry weight and transpiration data after Trumble (7).

TABLE II.—ANALYSIS OF VARIANCE FOR OSMOTIC PRESSURE DATA.

Factor				Degrees of Freedom.	Sum of sqq.	Mean sq	Standard Deviation
Time	..	..	..	5	88·033	17·607	
Treatment	..	..	..	7	155·932	22·276	
Remainder	..	..	..	35	247·645	7·070	2·66
Total	..	..	..	47	491·610		

$$z(\text{treatment : remainder}) = 1·475$$

$$1\% \text{ point} = <·6$$

* It must be appreciated that the method of obtaining sap by pressure after freezing gives a liquid whose resemblance to the vacuolar sap of the living cells is only approximate; and the numerous variants of the method cannot reduce considerably the degree of approximation. Freezing has been advocated by many workers because of the necessity of destroying the semi-permeability of the cell-membranes: the greater concentration of sap obtained after such treatment is regarded as being due to the release of ions otherwise held back by these membranes. Yet it would be expected that freezing would cause the release of colloidal adsorbed ions, although Dixon and Atkins (2) found that the sap obtained by this method would not plasmolyse the living cells and hence is presumably not more concentrated than that present in the vacuoles. In any case, it is probable that the osmotic pressure values obtained in the present work are sufficiently comparable to indicate the order of variability of the osmotic pressure of the true vacuolar sap in the material under investigation.

3. Discussion.

Examination of the data shows that certain of the manurial treatments had a pronounced effect on the dry weight of the harvests. Superphosphate (T2) has no appreciable influence; sodium nitrate, whether applied alone (T3) or in conjunction with superphosphate (T5, T7), increases the yield greatly; sodium chloride depresses it (T4, T6) and even counteracts the influence of sodium nitrate when applied in excess (T8).

Transpiration has been expressed as total water lost/total dry matter produced, a quantity known as the transpiration ratio. Superphosphate and sodium chloride, either singly (T2, T4) or in combination (T6), have no appreciable effect on this ratio*; sodium nitrate, however, causes a marked reduction in each case where it is applied (T3, T5, T7, T8).

The various manurial treatments will be seen also to have increased the osmotic pressure of the cell sap in the following order:—T2, T4, T3, T6, T5, T7, T8. The general drift of this order may be regarded from the z value as significant, although the positions of individual treatments cannot be so in view of the high standard error.

The relation of yield to manurial treatment presents no new features of fundamental significance, although it adds to our knowledge of the specific behaviour of *Atriplex*. Turning to our main object of consideration, the transpiration of the plants, the outstanding result is the marked reduction in the transpiration ratio caused by sodium nitrate. This effect is already well known (e.g. Wilfarth (8)), but its physiological interpretation is not yet established.

The only measure of transpiration available in the data before us is the transpiration ratio. This quantity, while of value as an index of the efficiency of the process of dry matter production with respect to water consumption, tells us nothing of the independent variations in its terms during the life of the plant. Let us consider two plants, A and B, B having a lower growth rate than A. Harvesting is deferred until B has attained the same dry weight as A. If the rate of transpiration per unit weight of both plants is the same throughout their life period, the total water loss of B, and hence its transpiration ratio, will be smaller than the same quantities of A. Nevertheless, although nitrates are known to retard the development of plants, it is unlikely that the marked reductions in transpiration ratio can mean other than a real reduction in the rate of transpiration per unit weight throughout at least the greater part of the life period.

The osmotic pressure of the cell-sap of the leaves may be expected to be a factor influencing transpiration. This possibility has already been investigated by Eaton (3) for the case of a reduction in the transpiration ratio of *Atriplex* which he obtained on treatment with sodium chloride. He found that, while the transpiration ratio and osmotic pressure were closely related, the actual increases in osmotic pressure were of a much lower order than would have been necessary to effect the corresponding reductions in transpiration.

It remains to be considered, however, whether the nitrate treatment could have achieved its effect on transpiration by increasing the osmotic pressure. It will be seen from Table I that transpiration ratio tends

* This does not agree with the results of Eaton, (3) who found that sodium chloride reduced the transpiration ratio of *Atriplex semibaccatum*.

to be a decreasing function of osmotic pressure, although here, where the different salts may have introduced secondary effects, the relation is not so precise as that obtained by Eaton. However, for T1 and T7, which show the maximum transpiration difference of 19 per cent., the osmotic pressure difference corresponds to a difference in vapour pressure of the sap of only 0.3 per cent., which is clearly negligible in its effect on water loss by evaporation.

We must therefore regard osmotic pressure and transpiration as being independently related to the supply of mineral nutrients. Eaton showed by conductivity determinations that in his experiments with sodium chloride the increased osmotic pressure of treated plants could be completely accounted for by the increased mineral-ion concentration of the sap.

Another possible explanation for the effect of nitrate on transpiration is that the ratio of leaf area to dry weight is reduced. While there is no evidence on this point for *Atriplex*, Gregory and Richards (5) found that nitrate-deficiency in barley caused a slight reduction in the ratio leaf-area/dry weight. Gregory (4), moreover, has shown that the increase in dry matter of barley produced by nitrate application is due to increase in leaf-area, the efficiency of assimilation remaining unchanged. Gregory and Richards (5) also found that nitrate deficiency in barley causes no significant change in the rate of photosynthesis per unit area. It is therefore unlikely that alteration in leaf-area/dry weight can be the explanation needed.

The mechanism of the reduction of transpiration effected by nitrate treatment will perhaps ultimately be found in the physical characters of the protoplasm of the mesophyll cells. To pass from the vacuolar reservoir to the intercellular space system, it is necessary for the water to pass through the protoplasm, and its rate of passage will be governed largely by the imbibitional and other properties of the protoplasmic colloids. Our knowledge of the effect of mineral ions on non-living colloidal systems leads us to believe that these properties will undoubtedly be influenced by manurial treatment. Recent work by Crist (1) and Pearsall and Ewing (6) suggests that such influence may indeed be the explanation of the phenomenon under discussion.

4. Summary.

The effect of nitrate treatment in reducing the transpiration ratio of *Atriplex semibaccatum* cannot be explained in terms of reduction of the osmotic pressure of the cell-sap. Other possible interpretations are discussed.

5. Literature Cited.

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- (2) Dixon, H. H., and Atkins, W. R. G.: *Proc. Roy. Dubl. Soc.* 13: 422.
- (3) Eaton, F. M.: *Amer. Journ. Bot.* 14: 212, 1927.
- (4) Gregory, F. G.: *Ann. Bot.* 35: 93, 1921.
- (5) Gregory, F. G., and Richards, F. J.: *Ann. Bot.* 43: 119, 1929.
- (6) Pearsall, W. H., and Ewing, J.: *Ann. Bot.* 43: 27, 1929.
- (7) Trumble, H. C.: *vide* p. 152.
- (8) Wilfarth, H.: *Bied. Zent. Agric. Chem.* 34: 167, 1905.

Note *re* An Improved Design for the 56-lb. Dried Fruit Box.

By Ian Langlands, B.E.E.
(Division of Forest Products).

One of the major problems of the Australian dried-fruit industry is the prevention of insect infestation of the fruit. In the last few years, a great improvement in the condition of the fruit on arrival at its destination has been effected by such measures as immunization of the fruit before packing, and fumigation of the packing and storage sheds, but in spite of all precautions insect attack still occurs. The general consensus of opinion is that the fruit is reasonably clean when it is packed, and that the major part of the infestation occurs after the fruit has left the packing sheds. Entomologists consider it likely that the damage could be very materially reduced if the containers in which the fruit is packed remained insect-proof. According to Dr. J. G. Myers,* "the fundamental element in the elimination of the pest (the *Plodia* moth) is the insect-proof container, which constitutes at once a preventative and an insurance."

The first step in the evolution of the ideal pest-proof container is the design of a box that will be capable of withstanding the rough handling encountered in transit from the packing sheds to the overseas consumer. In this regard, observations made during a visit to the Melbourne wharfs are of interest. In one consignment of dried fruit being loaded on an overseas liner, over 50 per cent. of the boxes were sufficiently damaged to allow free movement of the moth. That this is not an isolated case is shown by the fact that in another consignment, packed at a different shed, over 30 per cent. of the boxes were damaged. This damage occurred before the boxes were loaded into the ship, and it is safe to say that a great many more boxes would be damaged before the fruit reached its final destination.

In co-operation with Mr. A. V. Lyon, Officer-in-Charge of the Commonwealth Research Station, Merbein, the Division of Forest Products has carried out a comprehensive series of tests with a view to improving the design of the present type of box, the revolving drum described in a previous issue of this *Journal* (5: 68, 1932) being used to simulate the rough handling received in service. The tests showed that the fundamental weakness of the box as ordinarily constructed lies in the nailing. This is well illustrated in Fig. 1, which represents graphically the resistance to rough handling of boxes identical in construction except for the nailing. It will be seen that a box with four 1½-in. x 13 gauge nails in each end of the sides, and six 1½-in. x 14 gauge nails in each end of the top and bottom will withstand approximately five times as much rough handling as a similar box with three 1½-in. x 14 gauge nails in the side nailing edges, and four 1½-in. x 14 gauge nails in the top and bottom nailing edges, and approximately two and a half times as much as a box with four 1½-in. x 14 gauge nails in the sides, and four 1½-in. x 14 gauge nails in the top and bottom.

Even with four 1½-in. x 13 gauge nails in the side nailing edges, the nailing of the sides to the ends is still the weak point of the box. The number of nails, however, cannot be increased, as most nailing

* "Report on Insect Infestation of Australian Dried Fruits." Empire Marketing Board, 1927.

machines are incapable of driving nails closer than $1\frac{1}{2}$ inch. Moreover, increasing the size of the nails is impracticable, as it induces splitting, with a consequent reduction in strength.

The only other way of increasing the strength of the nailed joints is by the use of special high-holding-power nails. There are a number of different types of special nails on the market, but it was only possible,

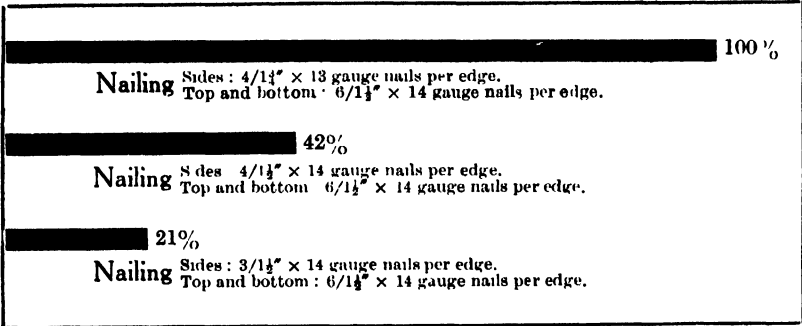


FIG. 1.—Effect of number and size of nails on resistance to rough handling. The horizontal bars represent the number of "drops" successfully withstood.

in the time available, to carry out tests on the two types most generally used, viz., barbed and spiral nails. The tests indicated that boxes using barbed nails are no stronger than those nailed with plain nails of the same size. The use of twisted nails, however, increased the strength (as measured by the number of drops successfully withstood) by about 66 per cent. That the increased holding power of the twisted nail is not sufficient to warrant a reduction in the size or number of the nails used was shown by the fact that boxes with four $1\frac{1}{2}$ -in. x 14 gauge twisted nails in the side nailing edges withstood 13 per cent. less rough handling than boxes with four $1\frac{3}{4}$ -in. x 13 gauge plain nails.

In order to determine the effect on the strength of the box of using improperly dried timber, boxes having four $1\frac{1}{2}$ -in. x 13 gauge nails in the side nailing edges and six $1\frac{1}{2}$ -in. x 14 gauge nails in the top and bottom nailing edges were made up of timber having a moisture content of 27 per cent. (based on the dry weight of the wood). The boxes were then allowed to dry until the moisture content had dropped to 17 per cent., when they were packed, strapped, and tested. The shrinkage of the timber caused the cracks between the boards to open, and, as shown in Fig. 2, the boxes so constructed had only 7 per cent.

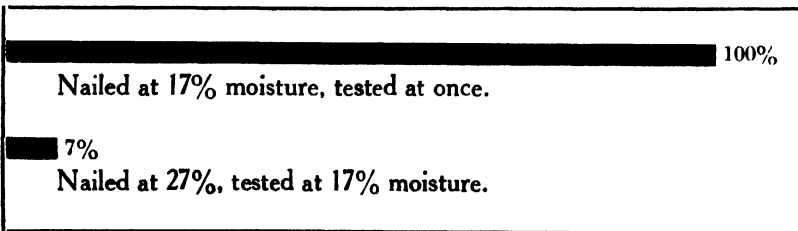
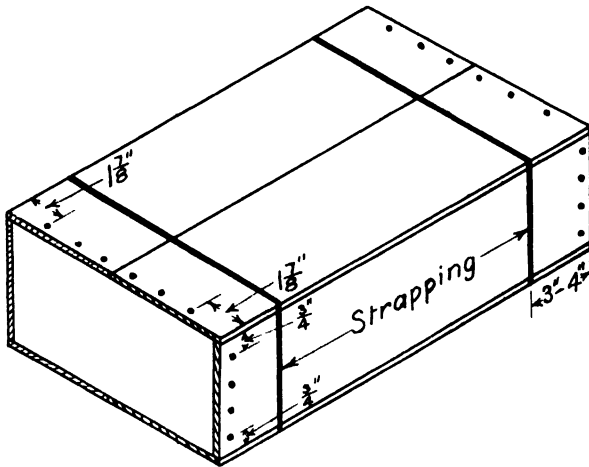


FIG. 2.—Effect of change of moisture content on serviceability of boxes similarly nailed. The horizontal bars represent the number of "drops" successfully withstood.

of the resistance to rough handling of boxes similarly made of dry material, thus demonstrating very forcibly the necessity for using thoroughly seasoned timber.

As the result of these tests, an improved box shown in Fig. 3 has been designed. It will be seen that no alteration has been made in the thickness of the timber, but the number and size of nails have been increased. Boxes made to this design will withstand considerably more rough handling before showing signs of failure than the boxes now used in the dried-fruit industry, and their adoption should be a big step towards the ideal of the insect-proof container.

When carefully made of accurately milled and well-seasoned timber and nailed according to the schedule indicated in the figure, the resultant box is fairly insect proof. As an additional precaution, however, it has been proposed by Dr. J. W. Munro, Entomology Department, Imperial College of Science and Technology, to provide the boxes with waxed crepe-paper liners, which are sealed after the fruit



Internal Dimensions $19\frac{1}{8}'' \times 12\frac{1}{8}'' \times 6\frac{1}{8}''$.
Thickness of top and bottom $\frac{1}{8}''$.
Thickness of ends $\frac{3}{8}''$.

Nailing

Sides, four $1\frac{1}{2}'' \times 13$ gauge nails per edge.
Top and bottom: six $1\frac{1}{2}'' \times 14$ gauge nails per edge. Nails uniformly spaced.

FIG. 3. Recommended design for a nailed 56-lb. dried fruit box.

has been packed. As there was some doubt as to the ability of the paper liners to withstand rough handling without tearing, particularly when the fruit has contracted somewhat and is free to slide about inside the box, revolving drum tests were made on several boxes provided with the above-mentioned paper liners. The tests showed that the paper envelopes are capable of withstanding a considerable amount of rough handling, in nearly every case the liner remaining intact even when the box was practically falling to pieces.

From the results of the investigations carried out it will be seen that the strength of the ordinary dried-fruit box can be very greatly improved by a simple alteration in the nailing, the increased cost per box being only a small fraction of a penny. It must be pointed out, however, that the benefits obtained by proper nailing can be to a large extent nullified by the use of inaccurately cut or improperly seasoned timber.

Scientific Papers from the Division of Economic Entomology published elsewhere than in the Council's Publications.

By R. J. Tillyard, D.Sc., F.R.S. &c., Chief of the Division.

During the progress of any line of entomological research, a number of useful results are obtained aside from the main economic result aimed at. Also, owing to the vast field covered by the science of entomology and the comparatively small number of workers employed in it, a considerable amount of work has to be done which contributes towards the main results aimed at, without actually forming a part of it. Generally speaking, all systematic and technical papers would come under this heading, as well as a considerable number of papers on life-histories and ecology. The practice of the Council is to permit such papers to be published elsewhere than in the Council's own publications, either in Australian scientific journals, or, if considered advisable, in those of other countries.

In this article, a list is given of the papers so far published in this manner by the Division of Economic Entomology, together with a short summary of each paper, so that those of the readers of this Journal who may be interested may be enabled to understand the ground covered in each case.

TILLYARD, R. J., 1929.—The Biological Control of Noxious Weeds. Fourth International Congress of Entomology, Ithaca, N.Y., 1928, Proceedings, vol. ii., pp. 4-9.

This paper gives a short summary of the general problem, the safeguards to be employed, and the progress of the work undertaken in Australia and New Zealand.

TILLYARD, R. J., 1930.—The Biological Control of Noxious Weeds. *Royal Society of Tasmania: Papers and Proceedings, 1929* (1930), pp. 51-86, pl. xi. (R. M. Johnstone Memorial Lecture, Hobart, October, 1929.)

The lecture sets out the general principles of biological control, and emphasizes the fact that the attempt to control a weed by means of its natural insect enemies is the inverse of the attempt to control the insect pests of a useful economic plant by means of their natural enemies. The organisms which are beneficial to man in the one case are harmful to him in the other, and vice versa. If the second type of attempt is justified, so is the first, but certain safeguards are necessary, and these are stated in detail. The lecture also gave a detailed account of the various attempts so far made to control noxious weeds in this manner, both in Australia, New Zealand, and elsewhere.

TILLYARD, R. J., 1930.—The Evolution of the Class Insecta. *Royal Society of Tasmania: Papers and Proceedings, 1930*, pp. 1-89. (Presidential Address to Section D, Australian and New Zealand Association for the Advancement of Science, Brisbane, June, 1930.) Second part only published also in the A.N.Z.A.A.S. volume for 1930, Presidential Addresses, Section D, 49 pp.

The first part consists of a review and criticism of the principal theories concerning the evolution of insects, more particularly Handlirsch's theory of their origin from Trilobites, Crampton's and Hansen's theories of their origin from Crustacea, and the various theories concerning their origin from Myriopods. All these, when tested, appear to fail in one or more important points. The second part sets forth a new theory of the origin of insects, in which the winged insects are traced back to a common origin with the wingless bristle-tails or Thysanure; this common stock, traced further back, unites with the ancestors of the Protura and the springtails (Collembola), and the resulting ancestor again is shown to have had a common origin with certain groups of primitive Myriopods. The hypothetical ancestral group is termed the Protaptera, and its characters are defined.

TILLYARD, R. J., 1931.—The Wing-Venation of the Order Isoptera. I.—Introduction and the Family Mastotermitidae. *Proceedings Linnean Society, N.S.W.*, lvi., pt. 4, pp. 371-390, pl. xxi.

One of the principal difficulties in the study of termites or white ants is their classification and the satisfactory recognition of the various genera and species. This is very important for the economic problem, since, in the past, damage of one type has been ascribed to species whose true habits are of an entirely different nature. While Mr. G. F. Hill is working out the main systematic problem for the Australian species, Dr. Tillyard undertook to study the development and structure of the wing-venation with a view to discovering how far this would help in the problem. The first part of his work deals with the giant termite of North Australia, *Mastotermes darwiniensis*, one of the most destructive species known, and gives the result of his analysis of the venational characters.

NICHOLSON, A. J., 1931.—Methods of Photographing Living Insects. *Bulletin of Entomological Research*, London, June, 1931, xxii., pt. 2, pp. 307-320, plates viii-xvii.

This paper gives the results of Dr. Nicholson's study of the problem of photographing living insects. Two methods are used, the first being in the field, by daylight, the second either in the field or laboratory, by flashlight. The main principle adopted is the use of a telescopic focussing attachment by means of which the insect can be focussed simultaneously with the taking of the picture. The ingenious methods whereby the telescope and camera lens are made to focus automatically on the same spot, and the flashlight fired to give a strong, even illumination of the object, are described in detail. A set of ten beautiful plates shows some of the results of the methods used, two of the most striking pictures showing the life-history of a mosquito, and a Nemestrinid fly hovering in mid-air.

HILL, G. F., 1932.—Australian Termites (Isoptera). Biological Notes and Descriptions of New Species. *Proceedings Royal Society of Victoria*, vol. xlv (N.S.), pt. ii, pp. 134.

This paper includes notes on the biology, distribution, and synonymy of five species and one variety of *Calotermes*, three species of *Coptotermes*, three species of *Heterotermes*, and three species of *Eutermes*. All of the *Calotermes* and one species of *Coptotermes* occur commonly

in living trees of commercial species of the genus *Eucalyptus*, whilst of the remaining species three are of considerable economic importance as destroyers of structural timber. Two species of *Calotermes*, one species of *Heterotermes*, and one species of *Eutermes* are described as new.

HILL, G. F., 1932. Australian Rhinotermes (Isoptera). *Proceedings Royal Society of Victoria*, vol. xlv.

The first two described species, *Rhinotermes intermedius* Brauer and *Rh. reticulatus* Froggatt, are regarded as being specifically distinct, whilst the remaining hitherto described species, *Rh. breinli* Hill, is proposed as a sub-species of the former. Three new sub-species are described, viz., *Rh. intermedius seclusus*, *Rh. int. actuosus*, and *Rh. int. derosus*, besides two forms of the soldier caste of Brauer's species. Comparative measurements of species and sub-species of *Rhinotermes* are given. All the above forms are known to be extremely destructive to structural timber.

HOLDAWAY, F. G., 1929.—The Pink Bollworm Situation in Australia. Fourth International Congress of Entomology, Ithaca, N.Y., 1928, Proceedings, vol. ii., pp. 73-80.

The pink bollworms are well-known pests of cotton. There occur in Australia not only the true pink bollworm, *Pectinophora gossypiella* Saunders, but also three other species, one of which is the Queensland pink bollworm, *P. scutigera* Holdaway. The original home and the world distribution of the pink bollworm genus are discussed in the light of Wegener's hypothesis of the origin of continents, which affords a satisfactory explanation of their occurrence as native species in Africa, Asia, and Australia.

HOLDAWAY, F. G., 1929.—Confirmatory Evidence of the Validity of the Species *Pectinophora scutigera* Holdaway (Queensland Pink Bollworm) from a study of the Genitalia. *Bulletin of Entomological Research*, xx., pt. 2, pp. 179-185.

A study of the genitalia of both sexes of the Queensland pink bollworm, originally named from the immature stages, confirms the validity of the species. Details of the comparative morphology of male and female genitalia of this species and of the true pink bollworm *P. gossypiella* Saunders, are given with figures.

HOLDAWAY, F. G., and EVANS, A. C., 1930.—Parasitism a Stimulus to Pupation: *Alysia manducator* in relation to the Host *Lucilia sericata*. *Nature*, London, cxxv. (3155), pp. 598-599.

Figures are given to prove that there is a relation between the stage in which the blowfly *Lucilia sericata* hibernates and parasitism by the Braconid wasp *Alysia manducator*. Of two lots of 100 full-grown larvae examined late in autumn in France, not a single one was parasitized, whereas of two lots of 100 puparia examined under similar conditions, one showed 88 per cent. parasitism and one 89 per cent. It appears, then, that parasitism gives a stimulus to pupation and overcomes the retardation normally experienced with falling temperatures.

HOLDAWAY, F. G., 1930.—Nutritional Status and Sex Determination. *Nature*, London, cxxvi. (3169), p. 131.

This is a preliminary announcement of experiments in which the sex ratio of the "flour beetle" *Tribolium confusum* Duval was altered by submitting newly-hatched larvae to starvation. The results suggest an increase in the proportion of males with one-day starvation, and show an increase in the proportion of females with starvation for two or three days. The average mortality was 1.2 per cent. The results cannot be explained as due to differential mortality of the sexes.

HOLDAWAY, F. G., 1930.—Field Populations and Natural Control of *Lucilia sericata*. *Nature*, London, cxxvi. (3182), pp. 648-649.

As a result of studies carried out in the field at Toulouse, in France, the author concludes that the most important factor in the reduction of blowfly population in carrion is the intense competition between blowfly larvae together with its associated predatorism on the part of certain species. An initial population of 50,000 *L. sericata* maggots in 2 lb. of meat was reduced to 231 flies, while in another experiment 60,000 were reduced to 30 flies. There is a definite ecological succession of insect species in carrion, *Lucilia sericata* being the first of the succession. No absolute idea of the part played by parasites and predators can be obtained without understanding first of all the inter-relationships of the various species inhabiting the carrion.

HOLDAWAY, F. G., 1932.—An Experimental Study of the Growth of Populations of the "Flour Beetle," *Tribolium confusum* Duval, as affected by Atmospheric Moisture. *Ecological Monographs*, June, 1932.

The rate of growth of populations of *Tribolium confusum* and their magnitude are shown to be dependent on the atmospheric moisture. The mechanism by which the population equilibria characteristic of different humidities are brought about is through the biological control which the insect exerts on itself. There is thus an interdependence of biological control and a physical condition, atmospheric moisture. The effect of humidity on the physiology of the stages which constitute the population has also been studied, and the conclusion reached that it is impossible to decide from a study of the physiological effects of atmospheric moisture what the effects of humidity on the population will be. The importance of population studies to economic entomology is stressed.

EVANS, J. W., 1929.—A New Species of *Nysius* from Australia. *Bulletin of Entomological Research*, xix., pt. 4, pp. 351-354.

The common Rutherglen Bug, *Nysius vinitor* Bergroth, is a well-known pest of fruit trees, vines, and vegetables. A new species *N. clevelandensis* is described from Queensland, related to the common species. Figures are given to enable the two species to be distinguished.

EVANS, J. W., 1929.—New Species of *Nysius* from South Africa. *Bulletin of Entomological Research*, xx., pt. 3, pp. 267-270.

Five species of *Nysius* are dealt with from South Africa, of which one, *N. binotatus* Germar, is a common household pest and attacks fruit,

potatoes, and sunflower seedheads. It is called by the Boers "stinkvlieg." Four other species are here dealt with, three of which are new to science.

EVANS, J. W., 1931.—Notes on the Biology and Morphology of the Eurymelinae. *Proceedings Linnean Society of N.S.W.*, lvi., pt. 3, pp. 210-226.

The Eurymelinae are a group of rather large leaf-hoppers which attack *Eucalyptus* by sucking the sap. They secrete a honeydew which is greatly appreciated by ants. But for the attacks of numerous parasites, they would cause great damage to the saplings on which they mostly live. The paper gives a large number of interesting details about the general life-history of the group, and also deals with the external and internal morphology.

FULLER, MARY, 1931.—The Life History of *Calliphora ochracea* Schiner. *Proceedings Linnean Society of N.S.W.*, lvi., pt. 3, pp. 172-181.

The blowfly *Calliphora ochracea* occurs along the coast and tablelands of New South Wales and Queensland. It is found chiefly in spring and autumn. The paper gives full details of the egg, larval instars, and puparium, and discusses the effect of temperature and humidity on the rate of development. The maggots thrive in carrion under experimental conditions, but have never been found in carrion in the field, nor are they known to attack living sheep. It is possible that they feed on the carrion of native animals.

FULLER, MARY, 1932.—The Larvae of the Australian Sheep Blowflies. *Proceedings Linnean Society of N.S.W.*, lvii., pts. 1-2, pp. 77-91.

This paper deals with the larval characters of twelve species of flies known to attack sheep, of which five are primary blowflies (three species of *Calliphora* and two of *Lucilia*), four are secondary blowflies, and three are tertiary flies. The object of the paper is to set out clearly the morphological characters by means of which any blowfly maggot found on sheep can be at once accurately determined. The most reliable characters are to be found in the structure of the posterior spiracles and in the shape of the oral hooks, both of which are figured for all twelve species.

WOMERSLEY, H., 1932.—Tasmanian Collembola of the Family Sminthuridae. *Royal Society of Tasmania: Papers and Proceedings*, 1931 (1932), pp. 1-11.

The springtails of the family Sminthuridae include the notorious "lucerne flea," *Sminthurus viridis* Linn., a very serious pest of clover and lucerne. Several introduced and native species are also injurious to various crops. The paper deals with the Sminthuridae so far known from Tasmania, and lists five introduced and two native species, both of which are described as new. The characters given will enable these different species to be clearly distinguished.

PLATE 1.

(Preliminary Investigations on the Cultivation of Indigenous Saltbushes, &c. See page 152.)

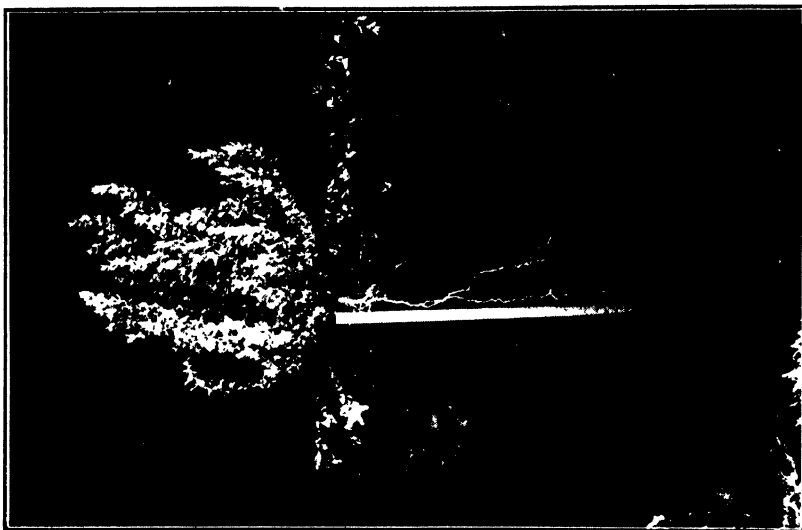


FIG. 1 (left)—*Atriplex semilacertum* and *Atriplex halimoides* at completion of first season's growth. Waite Institute, Adelaide, 1929-30.

FIG. 2 (right)—Excavated root system of a plant of *Atriplex vesicarium* twelve months old.

PLATE 2.

(Investigations on Flag Smut of Wheat. See page 165.)

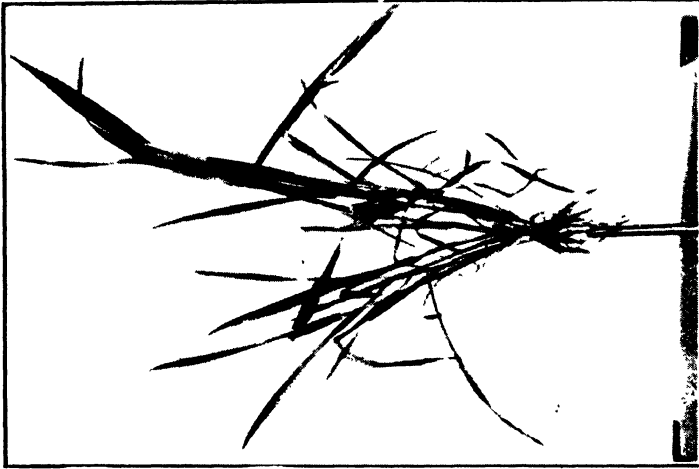


FIG. 3.—A healthy plant of the same age and variety as shown in Fig. 2. The height of the main shoot is 45 cms., and the average height of the five other taller tillers is 25 cms.

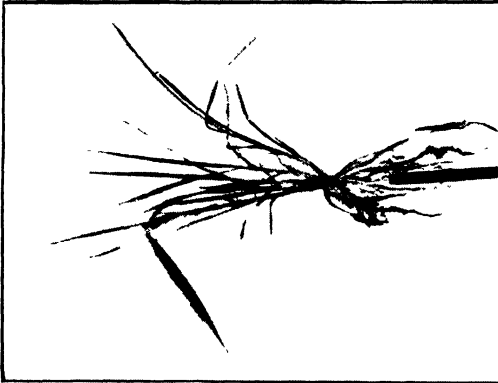


FIG. 2.—An infected plant of the "susceptible" variety (Glynas, 11 weeks after planting). The average height of the five tallest shoots of this plant is 17 cms. Each one of the nine shoots is infected.

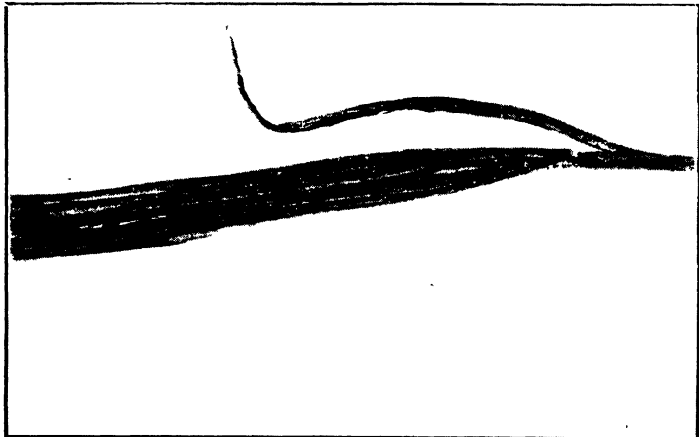


FIG. 1.—Portion of an infected leaf showing the parallel lines or spore characteristic of Flag Smut. The darker black areas show the spore ruptured and liberating the smut spore balls.

NOTES.

The Rabbit and Dingo—Suggestions for Control by the Dissemination of Disease.

From time to time, suggestions are put forward for the control of the rabbit pest in Australia by the dissemination of diseases. Similar suggestions have been made in regard to the dingo. Judging from the frequency with which these are made, the following brief discussion of the matter may be of interest.

In the first place, such proposals are far from being of recent origin. As long ago as the year 1888, M. Pasteur suggested that perhaps chicken cholera might be useful as a means of controlling rabbits. In the year 1897, the New South Wales Government made an offer of £25,000 for a satisfactory scheme whereby rabbits could be controlled by the introduction of disease. Some hundreds of schemes were put forward, and in the following year the Government formed a Royal Commission to consider them. The Commission summed up its conclusions as follows:—

“The Commission has found no evidence to warrant the belief that any known disease can be so employed as to exterminate rabbits.”

The Council and its forerunner, the Institute of Science and Industry, have consulted various authorities in regard to the possibilities under discussion. For example, in 1927, the Council obtained advice from the late Sir Harry Allen, formerly Professor of Pathology in the University of Melbourne, and also Chairman of the above-mentioned New South Wales Royal Commission. On that occasion, he stated, *inter alia*:—

“I am not hopeful concerning any scheme for destroying rabbits by infectious diseases. The evidence available tends to show that while there might be a large initial mortality, the disease would tend to die down like any other infectious disease, and a resistant strain of rabbits might easily be developed.”

The difficulties of discovering satisfactory diseases are summed up in the following extracts from a communication the Council received from Colonel Max Henry, Chief Veterinary Surgeon of the New South Wales Department of Agriculture, whom it consulted in 1928:—

“The question of utilizing diseases as a means of eradicating animal pests has often been suggested and many times tried, but so far there is no instance on record in which a successful issue has been obtained. . . . To be successfully employed in the eradication of noxious animals, a disease must successfully comply with certain criteria. In the first place, it must be a disease to which none of the domesticated animals or birds, or desirable wild animals or birds are susceptible; secondly, it must spread rapidly by direct and indirect contact; thirdly, it must not produce immunity. It will be readily recognized that it would be very difficult to pick out a disease which does not

fail in one or more of these points. . . . Even with so gregarious and numerous an animal as the rabbit, the problem of disease shows no encouraging prospects, and yet diseases are available for the work of a virulence not far below that of distemper."

The above comments were in response to an inquiry concerning the dingo—an animal of lonely habits, and thus even more difficult than the rabbit from the point of view of possible control by diseases.

Before leaving the question of the rabbit, it will be well to remember that, in 1906 and 1907, Dr. Danyz came out to Australia and carried out an extensive series of investigations on the possibilities of a virus he had obtained from Europe. It was found, however, that the effect of this virus rapidly died out. Further information regarding this work is contained in Commonwealth Parliamentary Papers 128 and 110 (1906), and 1, 138, and 147 (1907).

In so far as the dingo is concerned, suggestions have been put forward from time to time that possibly the use of distemper might be worth while. In 1927, inquiries were made by the Council regarding this suggestion. They indicated that eminent authorities such as Sir Charles Martin, formerly Director of the Lister Institute, and Chairman of the British Distemper Research Committee, and Professor Buxton, of the Department of Animal Pathology, Cambridge, definitely condemned the suggestion. They both considered that it would be almost impossible to start an epidemic, that even if started it would not secure the desired results, and that effective immunization of domestic dogs would be impracticable in Australia. The results of these inquiries were passed on to the recent Queensland Royal Commission on Rabbit, Dingo, and Stock Route Administration, and are quoted on page 130 of that report (1930). In 1930, at the request of the Commission just mentioned, further inquiries were made by the Council from Sir Charles Martin in order to ascertain whether more recent information would lead him to modify the opinions previously expressed by him. He furnished a large amount of information giving experimental details of the investigations carried out by the British Distemper Research Committee, and stated that these did not in any way lead him to modify his previous views. In particular, he pointed out that, like influenza in man, distemper in dogs is very infectious at close range, but the mortality is not high unless associated with secondary infections; that it is easy to produce an epidemic amongst caged or domestic animals, but difficult when they are distributed over a wide range under natural conditions; that recovered dingoes would be permanently immune; and that the only way to start an epidemic would be to catch a large number of dingoes, inoculate them with a virus, and let them loose amongst their companions.

In conclusion, it may be pointed out that the possibilities of controlling another animal—namely, the flying fox—by means of diseases are discussed by F. N. Ratcliffe, B.A., in the Council's Bulletin No. 53 (pp. 60-65). Here again, however, the author reaches the opinion that the possibilities are not attractive.

The Blowfly Problem—Arrangement re Testing of Proprietary Dressings.

From time to time, those engaged on research work into the blowfly problems are approached by owners of proprietary sheep blowfly dressings with a view to tests of such dressings being initiated.

In common with others, the Council has been approached on several occasions in the past. However, the Joint Blowfly Committee recently appointed to co-ordinate the work of the Council and of the New South Wales Department of Agriculture on the whole blowfly problem, has discussed the question of these tests. As a result, it has been arranged that in future all requests which the Council may receive for tests of proprietary specifics will be referred to the External Parasites in Sheep Sub-Committee of the New South Wales Department of Agriculture.

Buffalo-Fly Problem—Report by Professor E. Handschin.

Professor Handschin, of the University of Basle, and who for some time past has been located at the Veterinary Research Institute, Buitenzorg, Java, where he has been engaged on an investigation of the buffalo-fly problem (see this *Journal* (3): 66, 1930; (4): 234, 1931), has recently completed his two years' work, and has left Australia. Prior to his departure, he furnished the Council with a report, which it is proposed shortly to issue as one of the Council's pamphlets.

The report itself contains an amount of information having a direct bearing on the Australian problem. In the first place, considerable attention was given to the search for parasites, as it was thought that one of the reasons for the fact that the buffalo-fly is not a pest in Java was due to the existence there of a variety of parasites much more effective than any parasites that existed in Australia. Professor Handschin finds, however, that, of all the different kinds of parasites discovered, species of *Spalangia* are the only ones which hold any promise of successful results. The Javanese species of *Spalangia* examined lives about 27 days, lays 160 to 170 eggs, each egg in a separate puparium of a fly, and the life cycle occupies 18 to 21 days. Males emerge before females and come from eggs laid by virgin females. At Buitenzorg, the average parasitism of buffalo-fly puparia was about 8 per cent., but records as high as 46 per cent. were obtained in mountain regions. The North Australian species of *Spalangia* differs from the Javanese form in living about fifteen days only, and in laying only about 85 eggs. It is correspondingly less effective than the Javanese form. The amount of parasitism of buffalo-fly puparia recorded for Australia ranges from about 1 to 6.8 per cent.

Professor Handschin, however, has obtained some interesting results by crossing these two species, which action was taken with a view to evolving a more effective race. Using a special strain of Javanese male, which had been reared only on buffalo-fly puparia for several generations, it was found that the crossing of the Australian species with this insect caused the former to live up to 32 days instead of 15, and to produce 240 instead of 80 eggs. The reverse, however, that is crossing an Australian male with a Javanese female, caused the latter to live only ten days instead of seven, and to produce only 100 eggs instead of 180.

A supply of the above-mentioned effective cross of the Javanese male with the Australian female has been bred in Java, brought to Australia, and liberated at Burnside station, near Darwin.

In addition to the above breeding work, Professor Handschin and his assistants also gave an amount of time to the study of the life history of the buffalo-fly itself. As a result, they have obtained a considerable amount of information regarding the effect of temperature and humidity on the life cycle of the insect. It has been found, for instance, that the lowest effective temperature in which the fly can reproduce itself indefinitely is 22° C. (about 72° F.). With information of this nature, taken into consideration with the meteorological data that is available for Australian localities, it would be possible to forecast with much more certainty than hitherto possible the localities into which the fly may ultimately spread. On the evidence he has brought back from Java, Professor Handschin considers, for instance, that the buffalo-fly will not spread much further south than Rockhampton, Queensland. He regards it, in fact, as a "tropical animal." On occasions, he considers it may advance as far south as Brisbane, or even further, but he does not consider that it will maintain itself in such localities, owing to the fact that for rather lengthy periods the average temperature goes below 72° F.

Liberation of the Noogoora Burr Seed-Fly in Queensland.

The Noogoora burr seed-fly (*Euaresia aequalis*) was introduced into Australia from North America under quarantine conditions about eighteen months ago. Tests with this insect have recently been completed by the Council's Division of Economic Entomology in its quarantine insectaries at Canberra. The results have been entirely negative on all the economic plants tested, including cotton. Permission having been granted by the Commonwealth Department of Health for the liberation of the fly in Queensland, arrangements were entered into with Mr. R. Veitch, Chief Entomologist, Department of Agriculture and Stock, Queensland, for the carrying out of the actual liberation by one of his officers.

The area chosen was situated near Biloela, on the Callide Valley railway line, reached via Rockhampton. Noogoora burr grows densely in some parts of this area.

The first consignment of flies, consisting of 50 females and 50 males, was despatched from Canberra on Monday, 11th April. On arrival at Biloela, 32 females and 28 males were alive, and these were liberated on plants of the burr on 16th April. A further consignment, consisting of 58 females and 65 males, was despatched on 18th April. On arrival at Biloela, there were 43 females and 44 males surviving, and these were placed out in the same patch of burr as the previous consignment. A third consignment, consisting of 100 females and 100 males, was despatched to Biloela on 2nd May.

It is proposed to send future consignments to the Gatton district where arrangements for their liberation are being made.

Co-Operative Investigations into the Problems of the Cattle Industry of North Australia—Advisory Committee.

In the previous issue (p. 133), reference was made to the proposed setting up of an Advisory Committee in connexion with the above investigations. The arrangements for the investigations themselves, and the objects of the work, were outlined on that occasion.

Briefly, the Advisory Committee, which is representative of the co-operating interests, will advise the Council in regard to the conduct of the researches. The Committee itself has recently been established, and is composed of the following members:—

Representatives of the State Government:—

E. Graham, Esq., Under-Secretary, Queensland Department of Agriculture and Stock.

A. H. Cory, Esq., M.R.C.V.S., Chief Inspector of Stock.

Representatives of the Graziers' Association:—

F. M. Bell, Esq.; Norman Bourke, Esq.; D. M. Fraser, Esq.;
R. C. Philp, Esq.; E. E. D. White, Esq.; and J. L. Wilson, Esq.

Council of Agriculture:—

J. L. Wilson, Esq.

Council for Scientific and Industrial Research:—

Professor H. C. Richards (Chairman of its Queensland State Committee) (*ex-officio* member).

Black Disease of Sheep in France.

Until comparatively recently, this disease, termed by Dr. A. W. Turner, of the Division of Animal Health, Council for Scientific and Industrial Research, as a result of his exhaustive research into its pathology, bacteriology, and means of prevention, infectious necrotic hepatitis of sheep, has not been recognized as existing in France.

In the October, 1931, issue of *Compt. Rend. de la Soc. de Biol*, No. 29, Carré, Rinjard, and Debonera describe a disease of sheep under the name "hépatite nodulaire nérosante du mouton" (necrotic nodular hepatitis of the sheep). They have determined its existence in their flocks in three different parts of the country. They have "always found the characteristic lesions as described by Turner," the pathognomic lesions of the liver being "each a centre of multiplication of *B. oedematiens* and the diffusion of toxins." . . . "Losses occur at irregular intervals, and may become important." Among 148 ewes, which constituted one flock, 20 died of the disease between 1st July and 29th September. In another flock of 150 ewes, in a different district, there were 51 deaths during July, August, and September. "Our observations are entirely comparable to those of Turner in Australia, where the malady is known as black disease." In two of the outbreaks, the presence of the fluke (*Dicrocoelium lanceatum*) was determined, whereas that found in Australia is, of course, the *Fasciola hepatica*.

It is interesting to recall that black disease has also been proved to exist in Germany, as reported in a previous number of this *Journal* ((4): 191, 1931). It may be found, therefore, that this sheep malady, the complete elucidation of which has been due entirely to Australian workers, has a world-wide distribution. Indeed, it would be a matter of some surprise were it otherwise, seeing liver flukes are so widely spread, while the bacterial cause, *B. oedematiens*, has a universal distribution.

J.A.G.

Barium Compounds as Possible Wood Preservatives.

(Contributed by W. E. Cohen, B.Sc., Division of Forest Products).

The Division of Forest Products is anxious to find a substance which may be used for preserving timber used for internal work in dwellings and buildings. Such a material must necessarily be toxic or distasteful at least to termites (white ants) and borers, but, at the same time, it must not be sufficiently toxic to human beings to render it dangerous when used in such positions, nor must it seriously discolour or alter the appearance of the timber in which it is used. Further, it must be sufficiently soluble in water to enable it to be impregnated into the wood by a simple process.

During the past year, with the co-operation of the Division of Economic Entomology, the Division has carried out a number of laboratory tests with this object in mind. Small test sticks of *Pinus radiata* were impregnated with various concentrations of a number of materials, and these were submitted to termite colonies, held in captivity in screw-top jars stored in a room at a constant temperature. For each concentration of each substance under test, four sticks were impregnated. These four, together with two untreated sticks as controls, were placed in a jar containing active termites and some mound material. After a period of 20 days, one each of the treated and untreated sticks was removed and the degree of attack observed. After another twenty days, another pair was removed and examined. From this point, the two remaining treated sticks were left in the jar with active termites for a further 80 days, making a total time of test of 120 days. If, at any time during the test, the termites died or became inactive, the sticks were removed to another jar containing active termites and mound material. During this series of tests, the termites were particularly virile, and only a few changes were necessary. At the end of each test, the two remaining treated sticks were examined for the degree of attack.

Although there are still a number of aspects concerning these laboratory termite colonies that need to be investigated, it is considered that the tests so far completed serve to indicate what might be expected of a material in regard to its distaste with respect to termites.

A number of alkaline substances have been tested in the manner just described. These included sodium hydroxide, sodium silicate, sodium phosphate, borax, lime, and barium hydroxide. It is highly probable that the latter had changed to barium carbonate by the time the termite test was started.

Of all the above substances only barium hydroxide (or carbonate) proved to be sufficiently distasteful to the termites to prevent attack on the sticks impregnated with it. At the end of tests, sticks estimated to contain a little less than 1 lb. of barium hydroxide per cubic foot of wood were found to have been nibbled in a few places only, whereas the corresponding untreated sticks had been badly attacked as early as twenty days from the commencement of the test. Evidently, after the removal of the untreated sticks, the termites had investigated other sources of food and had nibbled at the treated sticks, only to find them unsuited to their taste.

It would be rather premature, and possibly unwise, to draw any definite conclusions from one such test as described above. However, it is considered that the results obtained from using barium hydroxide, as compared with those from using the other materials listed above, warrant further investigation, both of barium hydroxide and of other water-soluble barium compounds. It is, therefore, proposed to conduct further laboratory experiments, and also to test larger sticks, suitably impregnated, by placing them under service conditions in termite-infested areas.

As a wood preservative, barium hydroxide would, in many ways, be a very suitable material. For instance, the readiness with which it changes to the sparingly-soluble carbonate would enhance its usefulness in exposed positions as well as for internal purposes, although the same property would lead to complications in the actual impregnation process. During the work mentioned above, it was observed that the material had little or no effect on the appearance of the wood, and, in this regard, it would be very suitable for timber in which appearance is all-important.

From the results already obtained, it would appear that the barium is the influencing factor. Therefore, for use in protected positions, such as inside of dwellings and buildings, the more soluble barium compounds could more conveniently be employed. It is proposed to test these along with the hydroxide in the experiments which are now being undertaken.

A Card Index of Fungi recorded in Australia.

In 1895, a systematic arrangement of Australian fungi was published by D. McAlpine, and until the present time this has been the only record of its kind available to plant pathologists. To remedy this, the Council, on Mr. C. C. Brittlebank's retirement from his post as Biologist to the Victorian Department of Agriculture, commissioned him to compile a complete catalogue embracing all the records available in mycological literature to date of fungi occurring in Australia, together with a list of their host plants. Building on the records which he had already collected while an officer of the Department of Agriculture, he commenced his card index early in 1929. By June, 1931, he had consulted all references cited in appropriate literature and in unpublished records which were made available to him by the State Departments of Agriculture. As a result, he has indexed 6,078 fungi that have been recorded as occurring in Australia, including both parasitic and saprophytic species. A separate card was used for every species, and

appropriate cross-references were written wherever necessary. Each card records not only the name of the fungus and its synonymy, but also its host; and, in addition to stating where the first authentic record of its occurrence in Australia was published, gives also the other more important references in literature to it. As well as the fungi, the catalogue lists pathogenic bacteria and injuries to trees and plants caused by other agencies, such as malnutrition, gas, smoke, lichens, &c. A separate host index arranged alphabetically lists all fungi that have been recorded for each host.

Mr. Brittlebank's work is located at Canberra with the Division of Plant Industry, and is being kept up to date by the staff of that Division. It provides research workers, and all those interested in the field of plant pathology, with the means of knowing if an organism or a disease has previously been found in Australia, by whom and where, and all the relevant facts in regard to it. The experience of the compiler, and his world-wide recognition as an Australian mycologist, combined with his undoubted gift for caligraphy, make his plant disease survey of outstanding value in the field which it covers.

As the completion of the catalogue to date is not widely known, it is hoped that this brief account will bring recognition of its potentialities to workers to whom it will be of benefit. Although at present housed at Canberra, and only in card form, it can be consulted freely by accredited research workers.

Dr. B. T. Dickson, Chief of the Council's Division of Plant Industry, is, as time allows, preparing the material of the catalogue for publication, but it is obvious that an early issue is not possible. Meanwhile, mycologists and plant pathologists are requested to co-operate by forwarding to Dr. Dickson records of the occurrence of new organisms or diseases, new records of known organisms or diseases, and facts bearing on the incidental conditions and resultant losses.

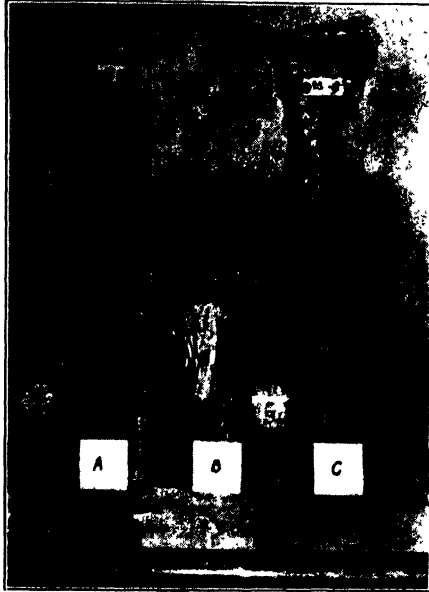
Rabbits and a Sodium Deficiency.

An international scheme for testing the value of a number of substances as wood preservatives was begun some years ago by the Forest Products Laboratory, Madison, U.S.A. Matched samples of softwood treated in various ways, together with untreated controls, are placed in the ground in termite-infested areas in several countries.

The Australian samples are located at Canberra and are periodically inspected by officers of the Divisions of Economic Entomology and Forest Products. During the course of the inspections, it was found that certain of the samples were badly eaten above ground by some animal obviously not a termite. In some cases, the whole of the specimen above the ground line had disappeared. Observation showed that the attack was due to rabbits and that the only specimens affected were those containing a sodium salt.

It is evident that the rabbits are suffering from a deficiency in sodium and that they are able to select the timber which contains this element. It has been found necessary to wire the specimens to protect them from the rabbits.

The photograph (below) shows: A, a specimen attacked below the ground line by termites, but sound above the ground. This contained no sodium salts. B and C both contained sodium salts. The former was eaten to the ground line and the latter only partly destroyed. C also shows the method now used to prevent rabbit attack.



Possibly if rabbits were supplied with a salt lick in young plantations, they might be induced not to destroy so many young seedlings. The loss by this in forest plantations is frequently severe. It would be of great interest and considerable practical value if it could be determined what essential food element the rabbits obtain from the seedlings. If this could be done, it would indicate a method of prevention which would be well worth a trial.

Recent Publications of the Council.

Since the last issue of the *Journal*, the following Bulletins and Pamphlets of the Council have been published:—

Bulletin No. 61.—"Studies in the Supplementary Feeding of Merino Sheep for Wool Production.—I.," by Hedley R. Marston.

This Bulletin gives the results of an experiment which was carried out at "Meteor Downs," Central Queensland, to determine the response in the wool growth by the merino sheep when the natural pasture, which during many months is deficient in protein, is supplemented by a protein-rich concentrate. The concentrate chosen was blood-meal, a slaughter-house by-product containing 80-85 per cent. protein, and approximately 2.7 per cent. cystine. In each of two years, it was found that the wool clip was increased by approximately 30 per cent., together with a corresponding improvement in bodily condition of the sheep.

Bulletin No. 62.—"A Soil Survey of the Cadell Irrigation Area and New Era, South Australia," by T. J. Marshall, B.Sc.Agr., and N. J. King, A.A.C.I.

As a result of the work reported in this Bulletin, four new soil types of River Murray irrigated soils have been defined. The salting problem at Cadell is also discussed.

Bulletin No. 63.—"Radio Research Board: Report No. 4." 1. A Preliminary Investigation of Fading in New South Wales, by A. L. Green, M.Sc., and W. G. Baker, B.E., B.Sc. 2. Studies of Fading in Victoria: A Preliminary Study of Fading on Medium Wave-lengths at Short Distances, by R. O. Cherry, M.Sc., and D. F. Martyn, Ph.D., A.R.C.Sc. 3. Studies of Fading in Victoria: Observations on Distant Stations in which no Ground Wave is Received, by R. O. Cherry, M.Sc.

In a country such as Australia, with its sparse population, its towns and cities separated by large distances, and its large areas to be covered by but few broadcast stations, a study of the fading of radio emissions is obviously of importance. The Bulletin reports the results obtained at various distances from several transmitters. The three different types of fading obtained at comparatively short distances (65-200 km. from the transmitters) and the two forms obtained at longer distances (590-870 km.) are described, and their probable causes discussed.

Bulletin No. 64.—"The Ripening and Transport of Bananas in Australia," by W. J. Young, D.Sc., L. S. Bagster, D.Sc., E. W. Hicks, B.A., B.Sc., and F. E. Huelin, B.Sc.; and in part by R. A. Holloway, B.Sc., B.E., and O. P. Barr, B.E., of the New South Wales Government Railways.

The methods of handling, packing, transporting, and ripening bananas at present employed in Australia are briefly described. It has been found impossible to ripen Queensland Cavendish bananas entirely satisfactorily unless some trace of some accelerating agent such as ethylene is present in the atmosphere of the ripening rooms. The conditions for the ripening of Queensland bananas have been fully investigated in Brisbane and Melbourne, and recommendations are made for commercial ripening under both summer and winter conditions. In addition, conditions under which green or partially ripened bananas may be stored for short periods have been investigated.

Pamphlet No. 27.—"The Possibilities of the Zebu Cross in Connexion with the Cattle Industry of North Australia," by R. B. Kelley, B.V.Sc.

The Pamphlet contains information gathered by the author while on a visit to the United States of America, and particularly Texas (where Zebu blood is used on a large scale in ranching operations), and to Great Britain. The main conclusion of the report is that, were the work adequately controlled, nothing but good would result from an introduction of Zebu blood into Australian tropical localities proved to be unsuited for British-bred cattle. Further, it is suggested that no country in the world has a greater inducement to verify experimentally the conclusions drawn by the author and other investigators.

Pamphlet No. 28.—"The Pig Industry: Report on Observations in Great Britain and America, with Suggestions Applicable to Australia," by R. B. Kelley, B.V.Sc.

The Pamphlet consists of a report of the author made after a visit to the United States and Great Britain. One of the main conclusions is that, in the production of pigs suitable for export, attention should be given to type, and not necessarily to breed, and due attention must also be given to the world-wide demand for lighter and leaner joints, be they from pigs, cattle, or sheep. The feeding of pigs for export is also discussed at some length, largely from the points of view of the nutritive ratios of food materials readily available in Australia, and of the balancing of diets.

Pamphlet No. 29.—"The Possibility of the Entomological Control of St. John's Wort in Australia—Progress Report," by G. A. Currie, B.Sc., B.Agr.Sc., and S. Garthside, M.Sc.

The Pamphlet is in the form of a progress report on the inquiries of the Council's Division of Economic Entomology into the possibility of controlling St. John's wort by insects. Special attention is being given in that work to three species of *Chrysomela*, to *Lathronympha hypericana*, to one or two gall midges, and to *Aphis chloris*.

Pamphlet No. 30.—"The Bionomics and Economic Importance of *Thrips imaginis* (Bagnall), with special Reference to its Effect on Apple Production in Australia," by J. W. Evans, M.A.

The Pamphlet consists of a progress report on the present co-operative investigations which the Division of Economic Entomology is carrying out in co-operation with the Waite Agricultural Research Institute and the Departments of Agriculture in the southern States. As well as giving information concerning the life history of the insect in question, the influence of meteorological conditions, the possibilities of forecasting "plagues," and the possibilities of minimizing the effects of the pest by cultural operations are discussed.

Forthcoming Publications of the Council.

Bulletin No. .—"The Sheep Blowfly Pest in Australia—Report of the Joint Blowfly Committee appointed by the Council for Scientific and Industrial Research and the New South Wales Department of Agriculture."

Bulletin No. .—"The Influence of Growth Stage and Frequency of Cutting on the Yield and Composition of a Perennial Grass—*Phalaris tuberosa*," by A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc., and R. E. Shapter A.A.C.I.

Bulletin No. .—"Downy Mildew (Blue Mould) of Tobacco in Australia," by H. R. Angell, B.Agr.Sc., Ph.D., and A. V. Hill, B.Sc.Agr.

Bulletin No. .—"Methods for the Identification of the Coloured Woods of the genus *Eucalyptus*, with a Tentative Key for their Identification," by H. E. Dadswell, M.Sc., and Maisie Burnell, B.Sc.

Bulletin No. .—"A Soil Survey of King Island," by C. G. Stephens, M.Sc., and J. S. Hosking, B.Sc.

Bulletin No. .—"Radio Research Board: Report No. 5.—Atmospherics in Australia," by G. H. Munro, M.Sc., A.A.I.M.E., and L. G. Huxley, M.A., D.Phil.

Pamphlet No. .—"The Collembola of Australia," by H. Womersley.

Pamphlet No. .—"Enzootic Haematuria (Haematuria Vesicalis) of Cattle in South Australia," by L. B. Bull, D.V.Sc., C. G. Dickin-son, B.V.Sc., and A. T. Dann, M.Sc.

Pamphlet No. .—"Investigations on the Buffalo-fly (*Lyperosia exigua* de Meij.), and its Parasites in Java and North Australia—Preliminary Report, by Professor E. Handschin."

Book Review.

"*Growth and Development of Mutton Qualities in the Sheep: A Survey of the Problems Involved in Meat Production,*" by John Hammond, M.A., of the Institute of Animal Nutrition, University of Cambridge, with a section in conjunction with A. B. Appleton, M.A., M.B. Pp. xiii + 597. Illustrations, 208. (Edinburgh: Oliver and Boyd. 1932.)

The author is a well-known and recognized authority on the genetics of domesticated animals. For both the geneticist and the stock breeder in general the work is of the utmost importance, although it concerns itself mainly with the mutton qualities of sheep. The investigations have been conducted over a period of twenty years, and were designed to "throw light on the biological problems involved in animal breeding in general and in meat production in particular," and much light has been thrown. The problem has been approached by observations on the meat, and by working backwards to find out the conditions or factors which affect its conformation.

A careful study has been made of the factors influencing the rate of growth of individuals, and the composition of the growth at different periods, the former being what directly concerns the farmer, the latter the butcher, but the combining of which should be the aim of the live-stock improver.

The treatise is divided into five parts: I. The rate of growth in live weight in a flock of Suffolk sheep. II. The carcass percentage, and the relative development of the different organs of the body. III. Variations in the rate of development of different parts of the skeleton. IV. Variations in the proportions of muscle, fat, and bone in the carcass. V. (in conjunction with Dr. Appleton) A study of the leg of mutton—the anatomy of which is dealt with minutely.

Space forbids any attempt at a *résumé* of the numerous observations and deductions. No criticism can be other than commendatory. The authors, and the publishers of the book, which is one of a series of Biological Monographs and Manuals issued by Messrs. Oliver and Boyd, and edited by Drs. Crew of Edinburgh, and Ward Cutler of Rothamsted, are to be congratulated. The book should form an important addition to the libraries of all Universities, Agricultural Departments, and Agricultural Societies.

J.A.G.

(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 5.

NOVEMBER, 1932.

No. 4.

Citrus Preservation Committee—Progress Report (October, 1932.)

In the *Journal of the Council for Scientific and Industrial Research* (1: 307, 1928,) an account was given of the formation of the Citrus Preservation Committee, and of its objects. The necessity at the time for the research work then proposed was summarized in general terms in the opening paragraph as follows:—

“For some time past, those connected with production of citrus fruit in Australia have felt that the industry could be expanded considerably if a means could be discovered whereby the fruit could be made available the whole year round, and whereby its condition could be maintained for a sufficiently long period to render its export to other countries possible.”

As previously stated, the Committee is representative of the following organizations:—

The Council for Scientific and Industrial Research;
The Victorian Department of Agriculture;
The Victorian Central Citrus Association;
The Victorian Railways.

A full account of the technique adopted was published in 1930 (this *Journal* 3: 69, 1930), and progress reports have been issued from time to time on the various aspects of the work (this *Journal* 4: 96, 1931. *Jour. Dept. Agr. Vict.* 29: 590, 1931).

One of the main investigations has been the study of the effects of treatment of oranges with preservative solutions, notably borax (5 per cent.), and sodium bicarbonate (2.5 per cent. and 5 per cent.), and the subsequent coating of the fruit with a film of paraffin wax. Other solutions have also been employed, including sodium sulphite, salicylic acid, and benzoic acid, but as these have had no definite effect, it is not considered necessary to discuss the results obtained by their use.

The experiments have now extended over four years, in each of which both Navel and Valencia oranges have been treated; and it is considered that a stage has been reached at which it is possible to come to a decision as to the benefits to be derived from such treatment.

Whilst in the first two years these tests were carried out with fruit from the Mildura district, oranges from other irrigation areas, such as Berri, Murrabit, Perricoota, Lake Kangaroo, and the Murrumbidgee

area, have been studied during the last two seasons, but no striking differences have been disclosed in the storage properties of fruit from these different districts.

The main object of the present communication is to give the general conclusions reached by the Committee as the result of this work, principally for the benefit of those sheds which may be contemplating the installation of washing and spraying plants.

Handling and Packing.

The experiments have confirmed the opinion that the advantages to be gained by handling all fruit carefully are considerable. Particular attention to shed hygiene, such as keeping all machinery with which the oranges may come in contact clean, and keeping the sheds free from dirt and old decaying fruit, is also strongly advocated. Packing too tightly is a consistent cause of damage to oranges, and in particular high packing and the consequent excessive bulge, with its unavoidable injury during lidding, are strongly deprecated.

Unpacked, loosely-filled cases of fruit show better keeping qualities in cold store than fruit wrapped and packed prior to storage.

In the experiments with Navel oranges, no advantage has been gained by the use of grease-proof or waxed papers in place of the cheaper and more easily handled sulphite tissue.

Washing.

Washing with 5 per cent. borax solutions or with either 2.5 per cent. or 5 per cent. sodium carbonate solutions has not shown, over the four seasons, that it definitely prolongs the life of Navel oranges in cool storage.

In almost all the experiments conducted by the Committee, the fruit was packed loosely into cases and railed to Melbourne, where it was treated and then packed in the commercial way. Under such conditions, the incidence of blue and green moulds, during the period that the fruit remains otherwise sound and palatable, was so small, even in the untreated controls, that no opportunity for material reduction in wastage from this cause has been offered.

In a number of cases, the incidence of mould has been reduced by the solutions at a late stage in the storage life of the fruit; but only at times when the fruit, due to the length of the storage period, had begun to collapse, lose its flavour, and become presumably more susceptible to mould attack. As the fruit at such times had no commercial value, because of its unpalatability, the protection from moulds was valueless. The solutions have no preservative effect, apart from their suggested influence, on mould attack.

With Valencia oranges, washing with borax had a definite effect in reducing the incidence of *Alternaria* (stem end rot), the chief cause of wastage after two or three months' storage. Sodium bicarbonate, on the other hand, has shown no consistent result in this direction. For Valencias, therefore, borax is to be preferred to sodium bicarbonate.

The washing treatment certainly improved the appearance of the fruit, especially when it was dirty; but it is improbable that the installation of washing apparatus could be justified on this ground, except when a large percentage of the fruit of a district was dirty.

Spraying with Paraffin.

With Navel oranges, no advantages have been observed—other than an improved appearance—when the fruit has been coated with paraffin wax subsequent to the washing treatment. When applied very lightly, no deleterious effect was observed, but heavier sprays actually shortened the life of the fruit. There is, therefore, a definite danger in the use of paraffin.

With Valencia oranges, no premature collapse of the fruit has been induced in any of the experiments by the paraffin spray. On the contrary, paraffin has usually lowered the amount of skin browning of Valencias, and further experiments upon this aspect are contemplated. Spraying with paraffin had almost as beneficial an effect in reducing stem end rot as had borax, the most effective treatment being a combination of washing with borax and spraying with paraffin subsequently.

As, however, the experimental Valencias when carefully handled were kept in good commercial condition without treatment for three months, and it was only at this stage that wastage due to *Allernaria* began to appear, the advantages of the treatment from a preservative point of view were confined to fruit stored for periods longer than, say, three months. It does not appear likely that, in practice, any considerable percentage of the Valencia crop of any district will be cool-stored for periods longer than this; and it is therefore improbable that the advantages to be gained justify the installation of the necessary apparatus.

Dirty oranges, however, both Navel and Valencia, are considerably improved in appearance by the treatment.

Temperature of Storage.

Taken over the four years, 38° Fahr. has been found to be the most satisfactory temperature for storage for both Navel and Valencia oranges. There have been indications, however, that storage at 45° Fahr. under conditions not yet determined may be superior for Navels, and experiments are in progress at the present time upon these conditions. Temperatures below 38° Fahr. appear to be quite undesirable.

Sweating.

From the limited experiments hitherto conducted by the Committee upon the "sweating" of oranges prior to packing, no definite results have been obtained. Work by Tindale and Fish of the Victorian Department of Agriculture, however (*Jour. Dept Agric. Vict.* 29: 101, 1931), has shown the possibilities of sweating at high temperatures in controlled atmospheres; and the Committee, having erected a special chamber in which temperature and humidity can be controlled, is collaborating with these workers. Experiments are at present in progress.

Commercial Storage Life.

The Committee would not advise the cool storage of Navel oranges periods longer than five weeks. After this length of time, a very ~~bad~~ deterioration of the appearance of the rind, and of the flavour

of the juice—usually referred to by the Committee as “collapse”—is liable to occur quite suddenly, and cause very serious loss. It is true that odd lots of Navels of exceptional keeping quality have been known to last in cool store for much longer periods than five weeks; but it is not considered that these are in any way typical of the bulk of our Navel crop.

From the export point of view, we would appear to be limited to ports not more than three weeks' steaming distance away. Under present conditions, export further afield would appear to be distinctly hazardous.

The Valencia orange has a much longer life in cool store than the Navel. With reasonable care, it can be kept approximately three months in store without prohibitive loss; and the onset of wastage is not sudden but rather progressive.

The export of Valencia oranges, should it become necessary, would present no serious difficulty.

Variations in Keeping Quality due to Season and District.

Although no precise data on this aspect have been secured, it is possible, as the result of the four years' experience, to come to the general conclusion that keeping quality does vary somewhat from year to year, and that the most important factor appears to be the rainfall in autumn and winter. 1929, a dry year, was a good keeping year; 1931, a very wet year, was a very poor one—from the trade's point of view it was frequently disastrous.

No marked differences between the storage properties of fruit from the various districts studied have been disclosed. This is perhaps to be expected, since they are all irrigated areas with a rather limited rainfall, viz., Mildura (including Merbein and Irymple), Curlwaa, Berri, Lake Kangaroo, Murrabit, Perricoota and Griffith. Nevertheless, the soil types vary widely from the very light red soils, such as Mildura and Perricoota, to the very heavy black soil of Murrabit. Climate is apparently more important than soil type. Thus, in experiments conducted by the New South Wales Department of Agriculture on fruit from the high rainfall, non-irrigated citrus areas north of Sydney, wastage—especially the loss from mould attack—is shown to be very much higher than has been experienced in the irrigated, dry-climate fruit studied by the Committee.

It is interesting to note that washing with borax in New South Wales has been found to reduce significantly mould infection on this apparently rather susceptible fruit. The type of fruit used by this Committee, on the other hand, appears to possess, when handled carefully, a much higher natural resistance to mould attack. Under such conditions, practically no further improvement can be brought about by the use of borax.

Fly Strike of Sheep: A Natural Phenomenon.

*By F. G. Holdaway, M.Sc., Ph.D.**

At the present time, there is in the press a comprehensive report dealing with all aspects of the blowfly problem in Australia. The report itself has been prepared under the aegis of the Joint Blowfly Committee of the Council and of the N.S.W. Department of Agriculture. It discusses all aspects of the problem such as biological control, dipping, swabbing, jetting, trapping, breeding for resistance, &c., and will be issued as soon as possible (at a price of about 1s. 6d. per copy) as a joint publication of the two above-mentioned bodies. In the meantime the Joint Blowfly Committee has recommended that the following article by Dr. Holdaway dealing with one aspect of the blowfly problem be published.—[Ed.]

Summary.

The theories which have been advanced in connexion with the fly problem in Australia are summarized and discussed briefly. A distinction is drawn between theories on what strike is and theories on the development of the fly problem in Australia.

Evidence regarding the attraction of blowflies, the oviposition responses of the female flies, the development of the larvae, and the succession of flies in carcasses and on living sheep is cited in support of the contention that bacterial activity in wool is a forerunner to strike in much the same way as bacterial activity on the skin and in the hair of dead mammals is a forerunner to attraction of flies and development of larvae thereon.

This contention is supported by our observations on strike in the field and by the experiments of C. R. Mulhearn and M. J. Mackerras. Johnston's theory that strike is associated with bacterial activity in the wool is thus considered to be proved, and Froggatt's theory that blowflies had changed their habits is considered unnecessary.

A study of conditions in the wool which favour or inhibit bacterial activity thus becomes an important aspect of the study of the blowfly problem.

1. Introduction.

When in Europe from 1928 to 1930, the writer made a general study of the facts available concerning the sheep blowfly problem. It was hoped thereby to open up additional lines of investigation which might prove of value in Australia. As a result of this study, the conclusion was reached that a satisfactory understanding of fly-strike in sheep was intimately connected with a knowledge of conditions favouring bacterial growth in the fleece.

In May, 1931, after the writer's return, an excellent opportunity for studying strike arose in the Riverina districts of New South Wales. The observations, made with Mr. C. R. Mulhearn, were concerned especially with "body strike," or fly attack on the body in places other than the breech, prepuce, and head. They were made concurrently with, though quite independently of, observations made by Dr. H. R. Seddon and his co-workers, and have given an opportunity for resuming the studies begun in Great Britain and for utilizing the information secured there. Further, they have shown that the conclusion reached earlier regarding the association of fly strike with bacterial activity in the wool was justified, and they have demonstrated in a striking way the importance of the bacteriology and the bio-chemistry of the fleece in relation to the fly problem.

* An officer of the Division of Economic Entomology.

During the early stages of the inquiries in Great Britain, I had the benefit of the advice of several workers, of whom I wish to mention, especially Dr. W. R. Thompson, Imperial Institute of Entomology, Farnham Royal; Dr. J. W. Munro, Imperial College of Science, London; Dr. Golding, Imperial Institute, London; Dr. S. G. Barker and staff, British Wool Industries Research Association, "Torridon," Headingley-lane, Leeds; and Dr. J. B. Orr, Rowett Institute, Aberdeen. In preparing the present paper and those which may follow, benefit has been derived from discussions with members of the Joint Blowfly Committee and my colleagues in the Blowfly Section of the Division of Economic Entomology. I am also indebted to members of the staff, particularly Mr. C. R. Mulhearn, Dr. M. J. Mackerras, and Miss Mary Fuller, for making available results of unpublished work. Observations on sheep in the field were possible through facilities readily provided by a number of pastoralists; their assistance is gratefully acknowledged.

2. Theories of Blowfly Strike.

Several explanations have been advanced to account for the development of the sheep blowfly problem in Australia. They are:—

1. Froggatt's theory of the change in habit of the native blowflies (13) 1904, (14) 1915. This theory was accepted in a slightly modified form by the New South Wales External Parasites of Sheep Committee (8) 1928.
2. Johnston's contention that gravid female blowflies were attracted to sheep and induced to oviposit on them as a result of bacterial activity in the soiled wool (19) 1923.
3. The contention advanced by Mackerras that the spread of the problem followed the spread of the European fly, *Lucilia sericata* Meig. (1) 1930. This theory has been adopted recently by Roberts (23) 1931.
4. The contention of Seddon, Belschner, and Mulhearn that fly attack became serious following the introduction of the wrinkly Vermont sheep (25) 1931.

In order to explain the development of the fly problem in Australia, it is necessary to understand (i) what fly-strike is, and (ii) how and why fly-strike developed in Australia.

Froggatt's theory was an attempt to explain both these phenomena. Johnston attempted to explain what fly-strike was. Mackerras, and Seddon, Belschner, and Mulhearn, were concerned with the development of the problem in Australia and not with the explanation of fly-strike in general.

In the present article, information available is used to answer the first of the questions given above, i.e., to explain what is involved in fly attack of sheep. It will be shown that Johnston's suggestion is sound, and Froggatt's assumption that the flies had changed their habits is unnecessary. In another article it is proposed to consider the theories of strike in greater detail, and to advance a new hypothesis on the origin of fly attack in Australia.

3. Oviposition by Blowflies on Dead Mammals.

Adhesion to the theory suggested by Froggatt that the flies had changed their habits* from ovipositing in carrion to ovipositing in the wool of living sheep is still fairly widespread and has found its way into the literature of other countries (22). It is perhaps natural that, in the absence of evidence to the contrary, such a theory should have been retained, for until Seddon's (26) recent publication describing fly attack on "water rot" of wool, Johnston's paper is the only publication which would be likely to dispel the idea.

The picture created by the word carrion is that of a mass of putrefying animal matter. As regards the main portion of the larval life of blowflies, such a conception is correct. But oviposition and early larval life occur in animals recently dead (Holdaway (17)). Further, although in dead mammals oviposition takes place in the moist openings of the body—the eyes, nose, mouth, and anus—a considerable amount of oviposition takes place also in the hair (Foreman and Graham-Smith (10)).

Experiments on rabbit carcasses which the writer made in France showed that oviposition by the European sheep blowflies, *Lucilia sericata* and *Calliphora erythrocephala*, is mainly in the fur. The rabbits were killed so that no blood was spilt, and the bodies were laid on the surface of the ground. Oviposition occurred, especially in the fur which was moist through contact with the ground, and the young blowfly larvae passed their early life, at least up to the beginning of the second instar, on the surface of the skin. Observations which the writer has made recently on dead sheep also show that, during the first few days after death, there is a considerable amount of oviposition in the wool.

Without considering for the moment the physiology of oviposition and larval nutrition, the fact that, in carcasses of mammals, oviposition occurs in the hair (or wool) and early larval development takes place in the hair and on the skin, while in strike oviposition is in the fleece and larval development takes place in the fleece and on the skin, suggests that fly strike in sheep is a natural phenomenon comparable to fly development on the carcasses of mammals.

4. Attraction and Oviposition of Blowflies.

Observations and experiments by many workers have demonstrated that the odours which attract adult saprophagous flies, particularly the gravid females, are products of fermentation or putrefaction. It is still unknown whether, for any species of fly, the attraction is the result of a specific odour or a combination of odours, but it is known that the activity of certain micro-organisms is responsible for the production of substances which attract the flies. The experiments of Foreman and Graham-Smith showed that prevention of such microbial activity on dead bodies by sterilization resulted in blowflies not being attracted to the bodies. It was not merely that blowflies were repelled by the creosote used, as carcasses treated with creosote all over, with the deliberate exception of small areas, had eggs laid on the untreated portions.

In general, oviposition by blowflies takes place on a medium suitable for the development of the larvae. However, it has been shown experimentally by Cousin (4), (5), (6), with *Lucilia sericata* Meig., and by

* Although Froggatt used the words "changed their habits," what he undoubtedly meant was that they had taken on a new habit in addition to those which they already possessed.

M. J. Mackerras with *L. sericata* and *Achaetandrus rufifacies* Macq.* that blowflies will lay their eggs on any medium which can provide the stimuli necessary for the oviposition reflex regardless of whether the medium is suitable for larval development or not. For example, flies sometimes lay their eggs on fruits, blankets, saddle cloths, and non-susceptible sheep on which the larvae cannot develop. When, therefore, blowfly larvae develop in nature, we have an association of two distinct phenomena, namely, (i) suitability of the medium for stimulating oviposition, and (ii) suitability of the medium for development of the larvae. This distinction is fundamental in the study of susceptibility to strike, for it indicates the necessity for determining not merely whether the sheep are attractive to the fly but more particularly whether conditions in the wool are suitable for larval development.

5. The Normal Development of Blowfly Larvae.

Soon after the death of an animal, the epidermis desquamates. Further, in the early stages of putrefaction there is pronounced bacterial activity on the skin. The larvae which developed from eggs laid on the rabbits mentioned above, passed the early portion of their lives feeding on the surface of the skin.

The larvae of saprophagous insects live in general in association with micro-organisms which partially digest their food (3), (15), (20), (28). However, cases of successful attempts to rear normal saprophagous larvae on a sterile medium are on record (2), (16), (30), (31). Frew (11), who also succeeded in rearing blowfly larvae aseptically, considered that their growth was not quite normal. Uvarov (28) sums up the evidence as follows:—"The absolute necessity of bacteria for the nutrition of the larvae is, therefore, doubtful, but this hardly affects the fact that normally the larvae develop on a substratum already liquefied by bacteria." Further, Hobson (15) says with regard to *Lucilia sericata*:—"Under favourable conditions the activities of bacteria will supply the larvae with partly-digested food. . . . In the absence of liquid food, the cells (of the mid-gut) will become free from fat and secrete more actively thus securing an increased liquefaction of the meat since a part of the tryptase is excreted."

One can state then that normally the nutrition of the larvae of primary blowflies, i.e., those early in the ecological succession in carcasses (17) and which initiate strike, is associated with bacterial activity; the bacteria are present on the skin and, provided there is adequate moisture, dead cells and other organic material form a suitable medium for their multiplication.

6. Succession of Insect Inhabitants in Dead Bodies and on Living Sheep.

A definite succession of insect visitors and insect inhabitants of putrefying animal matter has been recorded by several workers (21), (9), (17), and has been studied in detail by the writer in Europe and by Miss Mary Fuller in Australia.

This succession is no doubt intimately related to a succession of bacterial flora such as has been recorded by Effront and Prescott (7). Of particular interest to a study of the blowfly problem, is the fact that flies of the species which initiate strike are among the earliest visitors

* This species has had several names, but has been known especially as *Chrysomya albiceps* and *A. rufifacies*. (18.)

to dead bodies and oviposit there soon after death, whilst flies such as *Achaetandrus rufifacies* Macq., *Microcalliphora varipes* Macq., *Chrysomyia micropogon* Bigot, and *Peronia rostrata* R.D. appear later. The evidence to date, which has been collected by various members of the Blowfly Section and in particular by Dr. I. M. Mackerras, indicates that the production of strike by flies belonging to these four species usually, if not always, follows attack by a primary fly which is an early member of the succession in carcasses.

These facts suggest further that in fly-strike of sheep we have a phenomenon very similar to that associated with oviposition and larval development on dead bodies.

7. Bacterial Activity Associated with Fly Strike in Sheep.

If it be accepted then that bacterial activity is associated with the attraction of the female flies to places where they oviposit, with the provision of the stimuli necessary for the oviposition reflex and with the development of blowfly larvae in carcasses, and that if further there is a succession of fly visitors to the wool of living sheep similar to that occurring in dead animals, it would be logical to expect that fly-strike of sheep was also associated with bacterial activity. That this is so is now a demonstrated fact.

For bacterial activity, the two most important requirements are adequate moisture and a suitable nutrient medium. During the autumn of 1931, we had, in "body strike," an excellent example supporting the general thesis that bacterial activity in wool is a forerunner of strike. In these cases, it was possible to study strike under conditions devoid of the complicating features found in crutch-, prepuce-, or head-strikes. Moisture was contributed by continuous rains and the bacterial conditions which preceded strike were those referred to collectively as "weather stain" or "water rot." It was evident that in a certain number of sheep the fleece was suitable for bacterial growth except for adequate moisture which was later supplied by heavy, continuous rains. Much remains to be done on the bacteriology of the affected wool, but one organism associated with many of the cases of "weather stain" was *Pseudomonas aeruginosa* (*Bacillus pyocyaneus*). This species had been recorded from wool some time previously by Seddon and McGrath (24), and by Waters (29), and was isolated by Dr. M. J. Mackerras from wool which we collected. Confirmation that there is always a high bacterial count in wool prior to strike has since been obtained by C. R. Mulhearn and M. J. Mackerras.

Since the association of fly-strike with bacterial activity has been definitely established, it will be evident, after brief consideration, that "body strike" and "crutch strike" are essentially only phases of the same problem. In the case of "body strike," adequate moisture for bacterial development is supplied by rain and wet grass aided by dull or humid weather. In crutch strikes, which are in the main restricted to female sheep, the moisture is supplied by urine and wet faeces, while the maintenance of moist conditions in the breech is favoured by a high relative humidity. It is probable that the part played by the faeces when present alone is negligible, for male sheep are seldom struck in the crutch. Further, Cousin found that oviposition by *L. sericata* in faeces was restricted to the faeces of carnivora. It is

thus improbable that oviposition in soiled wool is due to the presence of the faeces as such, though it is possible that faeces may play a part in some way not yet fully understood.

As regards urine, it is possible that it acts as a skin irritant, but preliminary experiments indicate that it is detrimental to the development of larvae of primary flies. It appears then that the part which both urine and wet faeces undoubtedly play in crutch strikes is mainly that of wetting agents. The fact that fly eggs are often laid an inch or two away from the urine-stained wool, and also the fact that the larvae often move away from the "daggy" stained wool support this contention.

In another article it is proposed to discuss the conditions in wool which favour bacterial activity. The dead cells sloughed off from the skin and those passed out from the skin glands are no doubt important in contributing protein material, while of particular importance is the state of the wool yolk*. In crutch strikes, wrinkles play an important rôle in the retention of moisture. Further, the composition of the wool yolk on folds is different from that away from the folds. (Stewart and Rimington (27)), This also has a relation to bacterial activity in the crutch, and will be discussed at a later date. However, for the present, the main point is that it is necessary to conclude, as Seddon (26) has already done, that crutch strikes and body strikes are similar in that an essential predisposing feature of both is bacterial activity following wetting.

Our knowledge of the actual volatile substances which attract female blowflies to wool for oviposition is still incomplete. Raw wool is a medium composed of a number of complex substances—the wool fibre, wool yolk, and cell debris associated with it. The information available suggests that the volatile substances are the products of chemical changes in the constituents of the fleece as a result of bacterial activity. M. R. Freney (12) has recently shown that the products of hydrolysis of the wool fibre attract primary blowflies. The study of the chemical reactions associated with bacterial activity in wool should yield further information for our understanding of this aspect of strike.

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* Wool yolk, which is associated with the wool fibre and prevents matting, comprises, in the main, ether-soluble fats from the sebaceous glands, and the water-soluble suint or sweat from the sudoriferous or sweat glands.

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Caseous Lymphadenitis—The Disinfection of Shearing Machine Handpieces.

By H. R. Carne, B.V.Sc.*

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As infection of sheep with caseous lymphadenitis appears to result in the majority of cases from entry of the causal micro-organism through wounds of the skin, special attention has been drawn to the skin wounds occurring during shearing. It has been found that about 10 per cent. of infected sheep show evidence of rupture of superficial lymph glands, allowing the contents of the abscesses to run out into the wool. It is often observed also that lesions rupture during the process of shearing, due to pressure upon abscesses which are just about to break through the skin. The possibility of the shearing machine passing through such discharges, and thus becoming contaminated, presents a very ready means of transmission of the infection by the combs and cutters to subsequent skin wounds, which are inevitable in any but the plainest bodied types of sheep.

The following experiments were carried out with the object of finding a suitable means of disinfecting the shearing machine handpieces. During 1931, experiments were carried out using watery solutions of certain coal tar disinfectants, but complaints were made by the shearers that the frequent dipping of the hot handpieces into such watery solutions led to the lubricating oil being largely removed, with the result that combs and cutters had to be sharpened unduly often, and there appeared to be some danger of the oil being removed from the bearings of the handpiece.

Examination of handpieces after use showed that, under ordinary conditions, the crevices on the under surface of cutters became partly filled with a mass of greasy yolk, &c. It is believed that the heat generated by friction while the machine is running is sufficient to destroy any Preisz-Nocard bacilli which come into immediate contact with the combs or cutters; but where the yolk or pathological exudate is able to collect in a fairly thick layer, destruction of the micro-organisms will not take place.

It was proposed to disinfect handpieces after each sheep was shorn. There being but a short interval elapsing between the completion of one sheep and the commencement of another, disinfection required to be effected in a very short period while the shearer was catching his next sheep. The practice in earlier experiments in shearing sheds had been to dip the handpiece into a shallow layer of disinfectant in a kerosene tin immediately after completion of shearing. This dipping was only momentary, and then the handpiece was allowed to hang from its stand till the next sheep was caught. In order to effect rapid penetration of the masses of yolk and greasy caseous material which accumulate on the combs and cutters, it was deemed advisable to incorporate a fat

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solvent in the vehicle in which the disinfectant was incorporated. For this purpose, heavy mineral naphtha was selected as being cheap and efficient.

In the first series of experiments, the disinfectant was incorporated in a mixture of mineral naphtha and a lubricating oil commonly employed for lubrication of handpieces, the object being to avoid removal of lubricating oil during the process of disinfection. In later tests, the lubricating oil was omitted.

Technique.—Cutters from shearing machines, after thorough cleansing to remove all greases, were sterilized by autoclaving in petri dishes. They were then contaminated by smearing fresh caseous material from a natural lesion over the upper surface in a thin layer, and beneath, in the depressions on the under surfaces of the blades, a small mass of caseous material was deposited, just sufficient to fill the hollow tip. Such contaminated cutters were then immersed for 30 seconds at room temperature in the disinfectant solution to be tested. They were then removed and rapidly drained, and with a sterile swab the caseous material was rubbed off the upper surface. This was then rubbed up in serum broth. The masses from beneath were similarly removed and transferred to a second tube of culture media. The culture tubes were then incubated together with tubes sown from untreated caseous material from the lesion. Each test was duplicated.

The results of the various disinfectant mixtures are shown in the accompanying table.

Disinfectant	Concentration of Disinfectant	Vehicle.	Result.	
			Thin Layer.	Thick Layer.
Cresylic acid..	0.5%	Mineral naphtha 20%, lubricating oil 80%	+	+
Cresol (98%)	10%	Mineral naphtha 30%, lubricating oil 70%	+	+
Tricresol ..	10%	" " "	+	+
Titrol ..	10%	" " "	+	+
Titrol ..	1%	Mineral naphtha ..	+	+
Titrol ..	5%	" " ..	+	+
Titrol ..	10%	" " ..	+	+
Titrol ..	50%	" " ..	+	+
Cresylic acid..	1%	" " ..	+	+
Cresylic acid..	5%	" " ..	—	+
Cresylic acid..	10%	" " ..	—	+
Cresylic acid..	50%	" " ..	—	—

+ = Viable organism recovered.

— = No viable organisms recovered

The results of these experiments indicate that adequate sterilization with such a short exposure can be effected only by using disinfectants in considerable concentration. Admittedly the test employed was a severe one, because in practice the heat of the machine, generated by friction, is considerable, and would increase both the rate of penetration and the action of the disinfectant. In addition, it has been found in earlier field experiments that large accumulations of grease, &c., do not collect on the combs and cutters if these are dipped after each sheep.

Of the disinfectants used, cresylic acid proved to be the most satisfactory, but was capable of destroying all organisms only when used in a concentration of 50 per cent. in mineral naphtha. The addition of lubricating oil to the vehicle greatly reduced the efficiency of the disinfectant.

Because of the cleansing effects of the frequent immersion of combs and cutters of the handpiece into the disinfectant observed in field experiments, and the probable sterilization by heat of the organisms in immediate contact with the hot metal, it is considered that a concentration of 10 per cent. cresylic acid in mineral naphtha would be the most suitable of the disinfecting fluids tested. Cresylic acid, being a by-product of gas works, is comparatively cheap, and can be purchased in 5-gallon drums at 4s. 6d. per gallon. It consists of the higher fractions of the phenols, from which the carbolic acid and the cresols have been separated. Mineral naphtha costs from 2s. 3d. per gallon in 5-gallon lots.

We wish to express our great indebtedness to H. Finnemore, Esq., Lecturer in Materia Medica and Pharmacy of this University, whose advice was sought concerning the most suitable disinfectants and vehicles to use, and who kindly undertook the preparation of all the fluids tested.

A Soil Survey of Part of the Murrabit Irrigation Settlement (Vic.) and of the Bungunyah Irrigation Settlement (N.S.W.)

By T. J. Marshall, B.Sc.(Agr.)* and F. Penman, M.Sc.†

Summary.

Four new soil types have been identified and described at the irrigation settlements of Murrabit and Bungunyah.

Mechanical and chemical analyses are given, and particular reference is made to soil reaction, replaceable bases, and the bearing of the results on the use of gypsum and lime.

A comparison is made between the major soil type of each of these settlements and the river flat soils previously described in the soil survey of the Woorinen district.

1. The Murrabit Irrigation Settlement.

At the request of settlers, a soil survey was carried out at Murrabit, near Kerang, Victoria, to assist in the investigation of the general unthriftiness of many of the local citrus groves. The distribution of the planted blocks being scattered, a section known as Tye's Estate, having the greatest concentration of plantings, was selected for detailed soil survey. Results of the work reported here will probably be applicable to the remaining river flat land at Murrabit.

Tye's Estate is an area of 950 acres in the Parishes of Benjeroop and Murrabit West, and is part of the Murrabit Irrigation Settlement. It is entirely river flat land, and the only topographical feature is the depression known as Reedy Creek. The estate is only partly planted, and those blocks which have been improved are concerned almost entirely with citrus production. The remaining unimproved blocks constituting the bulk of the area are utilized for occasional crops, rough pasture, and, in a very few instances, for sown pasture.

The citrus groves in the Murrabit district as a whole constitute a small proportion of the total available area, and successful plantings are found generally on the blocks situated nearest the river. In general, Murrabit fruit is of high quality and has an excellent reputation. On Tye's Estate, plantings have been made on blocks well back from the river frontage, and the results have not been entirely satisfactory. The general backwardness of the greater number of the groves on the estate may be attributed to two main factors—frosts and soil conditions, associated in some instances with inadequate cultivation and irrigation practice. Bad frost periods have occurred during the drier winters. Thermograph records kept by Mr. J. A. Egan show that in 1929



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SOIL SURVEY OF TYE'S ESTATE

PARISHES OF
MURRABIT WEST AND BENJEROOP
COUNTY OF GUNBOWER

SOIL TYPES

MURRABIT CLAY ----- 
 BENJEROOP CLAY ----- 

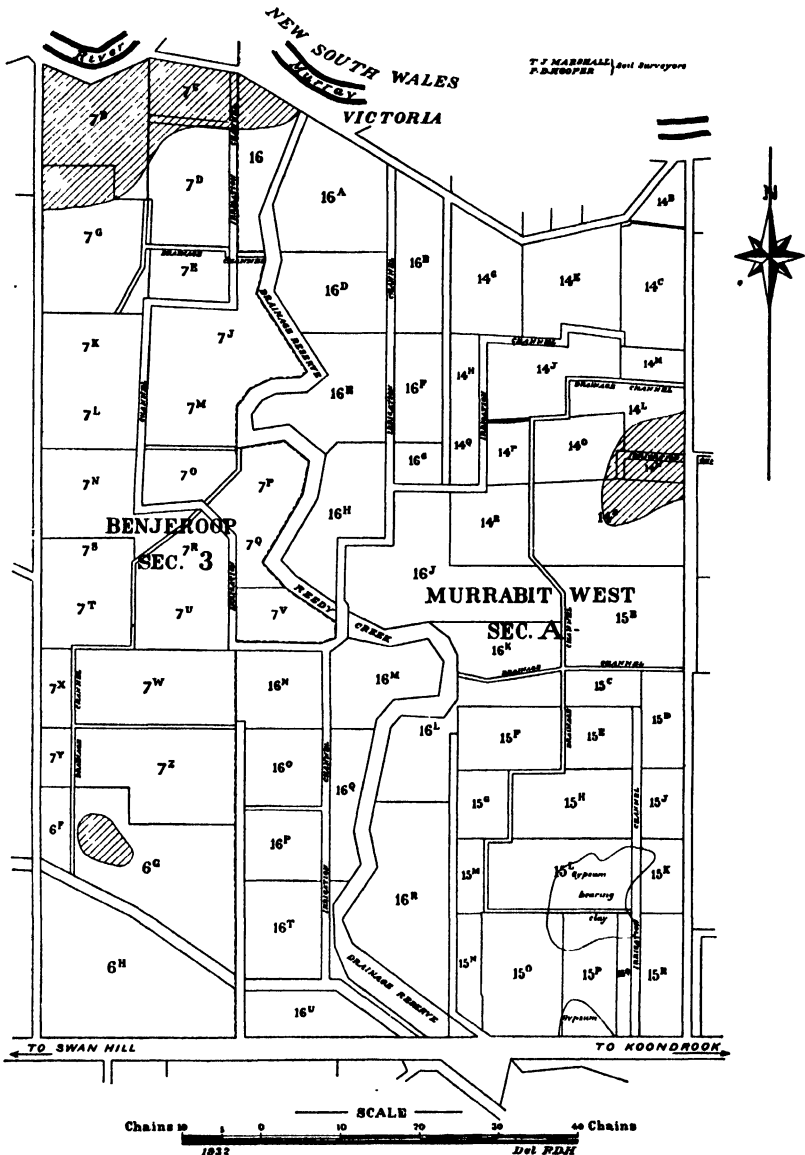


FIG. 1.

there were over 25 occurrences of frost, and that on nine occasions the temperature remained below 32° F. for a longer period than ten hours. Serious effects have followed the more severe frosts, and, as a precautionary measure, the lighting of heaters has been resorted to on some occasions. The check given to the growth and health of the orange trees must be a matter of great importance at Murrabit, but it does not account in full for the general lack of vigour.

(1) *Soil Types*.—Two soil types were described as a result of the soil survey, and their distribution is shown on the soil map (Fig. 1).

(a) *Murrabit Clay*.—This type covers the greater part of Tye's Estate, and is no doubt the chief soil of the Murrabit river flats. It is heavy throughout its profile, with a surface which is very difficult to work and to irrigate. The high clay content of the surface is maintained throughout the profile, which is illustrated in Figure 2A. Mechanical analyses (Table 1) show the texture of every sample taken to be that of a heavy clay. Soils of this nature present at the outset great obstacles to successful citrus production, and, moreover, tillage costs must always be an expensive item. The question of the improvement of the surface conditions, with respect to tilth and acidity, by the addition of gypsum or lime is discussed later.

A variant from this type, which occurs to a very limited extent on the estate, is mapped separately, and is indicated by the words "gypsum present in profile." This soil covers 14 acres, and yields but poor results with citrus.

(b) *Benjeroop Clay*.—In surface appearance, Benjeroop clay is similar in the field to the more common type described above, but on analysis it is seen to be rather lighter in texture (Table 1). The fundamental difference, however, is the presence at a depth of about 4 feet of notable amounts of fine sand, which increase with depth (Fig. 2B). The soil appears to be more satisfactory for citrus than Murrabit clay, and it is thought that many of the successful groves outside the area surveyed owe their success, in some part at least, to location on this more suitable soil type. It is probable that the type is of most common occurrence along the river frontage. The area within the estate is only 50 acres.

Murrabit Clay.

Heavy clay	8"	Dark grey
Heavy clay	30"	Dark grey with brown inclusions
Heavy clay	72" max.	Grey

FIG. 2A.

Benjeroop Clay.

Medium clay	8"	Dark grey
Medium clay with light brown inclusions	24"	Dark grey
Medium clay with brown fine sand in pockets	48"	Grey
Sandy clay, sand increasing	72" max.	Brown

FIG. 2b.

TABLE 1.—MECHANICAL ANALYSES AND OTHER DATA FOR MURRABIT AND BENJEROOP CLAY PROFILES.

(Figures represent percentages on air-dry soil, with the exception of pH.)

Soil Type	Murrabit Clay								Benjeroop Clay			
Sample No	638, 31/11	12	13	14	638, 31/19	20	21	22	638 31.1	2	3	
Depth in inches	0-8	8-24	24-48	48-72	0-8	8-33	33-53	53-73	0-8	8-24	24-48	
Coarse sand	0.2	0.1	0.2	0.2	0.6	0.6	0.6	0.4	5.8	5.8	7.4	
Fine sand	15.0	15.7	17.9	23.3	19.0	15.9	14.9	12.9	27.8	27.5	30.6	
Silt	19.9	18.4	20.1	26.1	23.3	23.2	22.6	24.8	13.2	16.1	13.6	
Clay	57.3	61.0	56.5	47.5	52.2	53.3	56.7	56.8	46.8	44.6	42.7	
Loss on acid treatment	3.6	3.3	3.3	2.2	2.5	2.1	2.0	2.2	3.0	2.1	2.8	
Loss on ignition	9.7	8.9	7.6	5.7	7.5	6.5	6.5	6.0	7.6	9.7	6.0	
Total salts	0.06	0.08	0.16	0.19	0.06	0.03	0.03	0.07	0.03	0.08	0.12	
Chlorine	0.02	0.02	0.07	0.07	0.01	0.00	0.01	0.02	0.01	0.04	0.06	
Total nitrogen	0.08				0.11				0.09	0.03		
pH	6.5	6.0	7.1	7.7	6.4	6.1	5.8	6.7	6.7	6.2	7.7	

(2) *Chemical Analysis*.—Analyses of hydrochloric acid extracts of typical Murrabit soils are shown in Table 4. Phosphoric acid is low and lime moderate, while potash and magnesia are high, the latter exceeding lime in all cases. Total nitrogen figures, as listed in Tables 1 and 2, are normal for heavy soils in this region, as is also the distribution of nitrogen in the soil profile.

The replaceable base figures listed in Table 5 characterize the Murrabit clay complex in surface and sub-surface samples as calcium-magnesium dominant, these two cations being present in roughly equal amount, and together constituting nearly 80 per cent. of the total replaceable bases. There is no free calcium carbonate in these soils, and the reactions of surface samples range closely round an average figure of pH 6.6. Reaction values of all Murrabit samples examined are set out in the form of a distribution table (Table 6).

Tables 2 and 3 show that, in general, chloride is the most important anion in soluble salt extracts. Figures for chlorine as shown in the tables represent chlorine in the form of chloride. From Table 3, and on comparison with similar soils of northern Victoria, soluble salt is attributed chiefly to sodium chloride and sodium sulphate, lime and

magnesia being of little importance. Bicarbonate is low compared with the calcareous alkaline soils of most of the Murray irrigation districts. It will be noted from Table 2 that chlorine reaches figures as high as 0.08 per cent. in some subsoils, and total salts, excluding the gypsum-bearing soil, reach 0.23 per cent. It is considered that in heavy soils of this character such figures for subsoils are not unduly high.

TABLE 2.—TOTAL NITROGEN, TOTAL SOLUBLE SALTS, AND CHLORINE IN MURRABIT CLAY AND BENJEROOP CLAY SAMPLES.

(Figures represent percentages of air-dry soil.)

Soil Type.	Murrabit Clay.						Benjeroop Clay.				Gypsum Bearing Soil.		
Sample No.	638/ 31/15	16	17	18	23	24	638/ 31/7	8	9	10	638/ 31/4	5	6
Depth Inches	0-8	8-30	30-58	58-72	0-6	6-24	0-8	8-24	24-40	40-60	0-10	10-24	24-42
Total nitrogen	0.09				0.09	0.05	0.11				0.06		
Total salts	0.07	0.07	0.15	0.17	0.10	0.23	0.06	0.08	0.12	0.07	0.09	0.23	0.65
Chlorine	0.02	0.02	0.05	0.05	0.02	0.08	0.01	0.01	0.02	0.02	0.02	0.07	0.11

* Containing gypsum.

TABLE 3.—ANALYSES OF SOLUBLE SALTS IN MURRABIT SOILS.

(Figures represent parts per 100,000 of air-dry soil.)

Sample No.	638/31/3	5	17	19	22	24
Depth Inches	24-48	10-24	30-58	0-8	53-73	6-24
Total salts	120	225	150	55	70	230
Cl	48	68	45	5	15	77
CO ₃	nil	nil	nil	nil	nil	nil
HCO ₃	12	10	20	13	9	14
SO ₄	13	63	36	8	8	62
Ca	1	7	1	1	0	5
Mg	2	5	2	2	1	7

TABLE 4.—CHEMICAL ANALYSES OF MURRABIT AND BUNGUNYAH SOILS.

(Per cent. air-dry soil.)

Soil type	Murrabit Clay.		Benjeroop Clay.		Bungunyah Clay.	
Sample No.	638/ 31/11	19	638/ 31/1	2	2389	2399
Depth Inch	0-8	0-8	0-8	8-24	0-12	0-15
P ₂ O ₅	0.08	0.08	0.05	0.05	0.04	0.04
K ₂ O	0.85	0.79	0.68	0.66	1.03	0.97
CaO	0.38	0.24	0.27	0.26	0.65	0.57
MgO	0.48	0.37	0.41	0.59	0.76	0.78

TABLE 5.—REPLACEABLE BASES OF MURRABIT AND BUNGUNYAH SOILS.

Soil type	Murrabit Clay.		Benjeroop Clay.	Bungunyah Clay.	
Sample No.	638/ 31/11	12	638/ 31/2	2389	2399
Depth—Inch	0-8	8 24	8 14	0 2	0 15
pH	6.5	6.0	6.2	7.9	7.4
Total replaceable base mgm. equivalent per cent.	33.3	30.5	26.0	29.7	28.9
Per cent. of total replaceable bases					
Ca	43	33	33	53	57
Mg	35	43	43	26	27
Na	18	21	20	15	10
K	4	3	4	6	6
Clay percentage	57.3	61.0	46.8	43.0	46.9

TABLE 6.—DISTRIBUTION TABLE FOR pH.

(Figures represent numbers of samples falling into each reaction range. Samples below 4 feet are not included.)

Reaction pH.	4.5- 4.9.	5.0- 5.4.	5.5- 5.9	6.0- 6.4.	6.5- 6.9.	7.0- 7.4.	7.5- 7.9.	8.0- 8.9.	8.5- 8.9
Swan Hill clay ..	1	2	1	1	1	..	..	..	..
Murrabit clay	2	5	5	1	..	..	..
Benjeroop clay	1	2	1	2	..	..
Bungunyah clay	2	4	4	1	2
Beverford clay loam	8	9

(3) *Discussion of Murrabit Soils.*—It is generally supposed at Murrabit that the soils there are all highly acidic, but this view has not been supported very strongly by the determinations recorded in Table 6. While practically all samples from the Murrabit clay soil type are definitely acidic, the degree of acidity, in surface samples at any rate, is in no case great enough to warrant concern. Lime has in the past been used in considerable quantities by some growers with the object of overcoming acid conditions. That this can be readily accomplished is shown by the fact that in two cases where this treatment had recently been adopted, an alkaline reaction (pH 7.7 and pH 8.0) was found for surface samples. These were the only alkaline surface samples taken at Murrabit, and because of the special treatment they had received the results have not been recorded on the pH distribution table.

The replaceable base figures are of considerable interest. The soils at Murrabit compare rather unfavorably with Bungunyah clay in respect to replaceable calcium, and this, coupled with their somewhat higher clay content, probably accounts for their inferior surface texture. The use of lime and gypsum with the aim of remedying this defect has been adopted fairly generally. Both materials will effect a gradual

improvement in the general condition of the soils by building up a calcium clay. Lime, of course, will have the additional value of correcting acidity where this is considered necessary, and is recommended for most soils of the district.

The problem at Murrabit, so far as it concerns the soil, is linked up with textural conditions rather than with infertility or acidity. Efforts at improvement must centre around the application of lime and gypsum, and notable results will necessarily be slow owing to the very high clay content of the soil. Normal fertilizer applications of nitrogen and phosphoric acid in some form are, of course, advisable in addition.

In watering of Murrabit soils, which in general may be considered free from seepage and salt troubles, and in which the chief problem is the extremely slow penetration of water, irrigation practices involving flooding or semi-flooding would appear to be the most satisfactory.

2. The Bungunyah Irrigation Settlement.

(1) *General*.—The Bungunyah-Koraleigh Irrigation Trust District is situated on the New South Wales side of the Murray River, opposite Nyah (Victoria), on a low flat, at a level formerly reached by high floods. To the east, the ground dips into Lakes Wollare and Goonimur, and to the west it rises to the Mallee country. The intervening strip includes about 1,400 acres of land, most of which is irrigable from low lift channels; of this area, only about 500 acres have so far been planted. Plantings consist chiefly of sultanias, with oranges occupying the major part of the remaining irrigated land. The flat is rather subject to frosts, and during 1928 and 1929 citrus growers experienced a good deal of trouble from this source. Taken generally, the trees have not come forward successfully since then, and at the time of the survey only occasional good groves were encountered.

The soils are mainly heavy and dark, the texture of the major type varying from a medium to a heavy clay, and the colour from dark-grey to black. Excluding the brown Mallee soils which project in places into the flat, the soils may be divided into two main types—Bungunyah clay and Koraleigh sandy loam, of which the former is by far the more important (*vide* soil map, Fig. 3).

Bungunyah Clay.—This soil type, the profile of which is sketched in Figure 4A, covers the greater part of the settlement. The depth of the dark-coloured horizon varies very considerably, and in local patches the surface is grey. In some borings the depth of the black clay was 26 inches, but in more than half the soils it was not greater than 12 inches. In the surface 2 feet of soil, lime was found in very limited amounts, if at all. In the subsoil, it was usually present in appreciable but never large amounts in association with fine limestone rubble. The soil, although very heavy and intractable when wet, becomes more friable and works into a reasonably good tilth when dry. The reaction of the normal profile is alkaline, but not highly so in the surface soils. Plant food analyses (Table 4) disclose the usual high potash and low phosphoric-acid content common to most Murray River soils. Total

SOIL SURVEY OF BUNCUNYAH-KORALEIGH IRRIGATION TRUST DISTRICT

PARISH OF BUNCUNYAH
COUNTY OF WAKOOL

T. J. MARMALL
Soil Surveyor

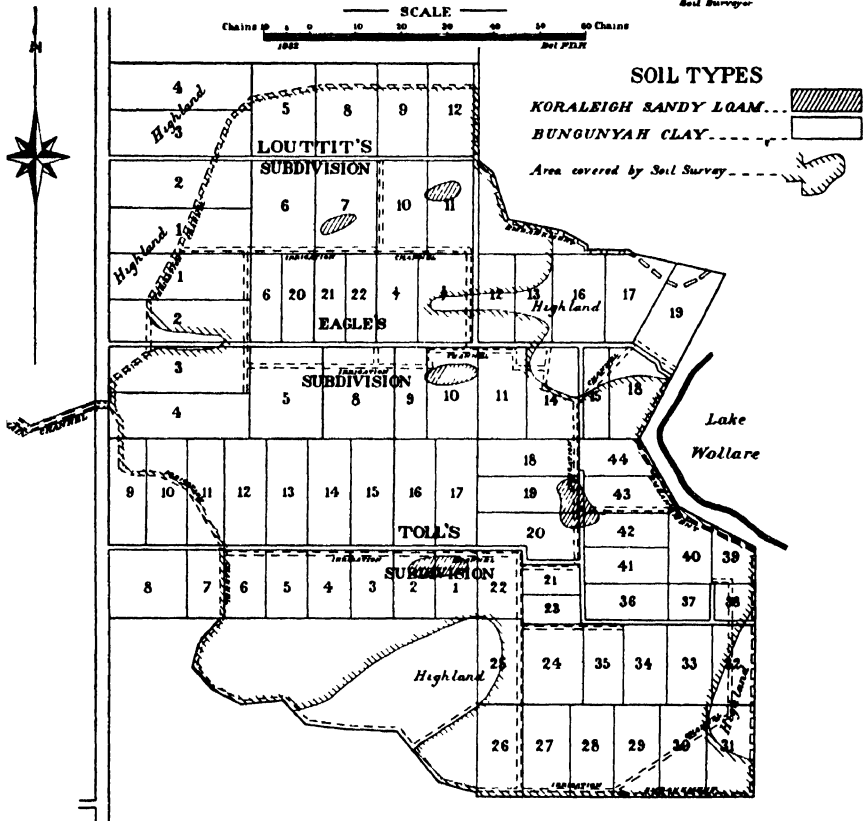


FIG. 3.

nitrogen figures, as shown in Table 7, are fairly high for surface and sub-surface samples when the depth of sampling is considered, one figure being 0.17 per cent. for the surface foot.

There are three variants from the normal Bungunyah clay soils, the most important of which appears, in the field, to be of a somewhat lighter texture. This is reflected in the mechanical analysis of samples 2389, 2390, and 2391 (Table 7). Otherwise, the soil presents no marked differences from the more usual type represented by samples 2399, 2400, and 2401.

A second variant occurs in blocks 40, 41, and 42 (Toll's subdivision) on land which has only recently been reclaimed, and has hitherto been subjected to repeated inundation. The soils here are exceptionally heavy (samples 2395-7) and slightly acid, and do not work down to the tilth of the normal type. Otherwise, the profile presents no great differences.

A third variant is found in blocks 34 and 35 (Toll's subdivision), which is also a low-lying area. Here the soils are greyer in colour, but still fairly high in nitrogen. Although also slightly acid, the surface does not present the same working difficulties as the heavy surfaced soils described above.

Koraleigh Sandy Loam.—This soil is of high productive capacity, but it is limited in extent to an area of 23 acres. The soils are light and highly alkaline. A typical profile is illustrated in Figure 4B, and

Bungunyah Clay.

Medium clay	12"	Black
Heavy clay with slight lime	20"	Grey black
Heavy clay with light lime and rubble		Grey

FIG. 4A.

Koraleigh Sandy Loam.

Sandy loam	15"	Dark grey
Sandy loam	26"	Brown
Sand with slight rubble		Brown

FIG. 4B.

TABLE 7.—BUNGUNYAH SOILS—MECHANICAL ANALYSES AND OTHER DATA.
(Figures represent percentages of air-dry soil, with the exception of pH.)

Soil Type.		Bungunyah Clay.										Koraleigh Sandy Loam.			
Sample No.	.. .. .	2399	2400	2401	2389	2390	2391	2395	2396	2397	2398	2398	2392	2393	2394
Depth Inches	.. .. .	0-15	15-30	30-50	0-12	12-30	30-50	0-11	11-18	18-38	38-58	0-12	0-15	15-36	36-56
Coarse sand	.. .. .	14.6	14.9	11.6	16.6	15.0	15.8	8.4	8.8	9.2	..	..	29.0	30.8	..
Fine sand	.. .. .	28.3	26.8	25.0	31.6	29.2	30.6	25.0	24.0	25.2	..	..	47.4	45.3	..
Silt	.. .. .	5.7	5.5	6.0	5.1	5.4	5.7	7.2	6.6	6.8	..	..	4.9	3.1	..
Clay	.. .. .	46.9	48.7	51.0	43.0	45.4	41.7	54.2	55.1	54.7	..	..	15.3	18.9	..
Loss on acid treatment	.. .. .	1.8	1.7	5.5	1.9	4.5	6.1	1.6	1.8	1.9	..	..	0.6	4.0	..
Loss on ignition	.. .. .	5.1	4.6	5.5	4.7	5.0	5.3	5.9	5.5	4.7	..	..	2.7	4.1	..
CaCO ₃	.. .. .	tr.	..	4.0	0.2	3.1	4.7	..	..	..	..	..	..	..	..
Total salts	.. .. .	0.04	0.05	0.11	0.09	0.16	0.16	0.09	0.05	0.08	0.21	0.08	0.05	0.10	0.10
Chlorine	.. .. .	0.01	0.01	0.02	0.02	0.05	0.03	0.01	0.01	0.02	0.04	0.01	0.01	0.02	0.01
Nitrogen	.. .. .	0.10	0.07	0.03	0.08	..	..	0.10	..	..	..	0.17	0.05	..	..
pH	.. .. .	7.4	7.9	8.5	7.9	8.0	8.7	6.8	7.2	7.4	7.9	6.8	9.0	9.0	9.5

the mechanical analyses are shown in Table 7. Soils of a heavier texture are also met with, and lime was found in the profile at a depth of about 15 inches in a number of borings.

(2) *Discussion of Bungunyah Soils.*—The problem of major importance at Bungunyah is the poor grade of dried fruit produced. Heavy yields are obtained, but with the exception of the small area of Koraleigh sandy loam, which is claimed by the owners to grow superior fruit, the sultanas are on the whole of low grade. The inference is that the adverse factor lies in either the soil or the climatic conditions. The latter are known to be unsatisfactory for the later stages of the harvest. In view of the high yield, it seems certain that the soil moisture and nitrogen supplies are ample. The production of abundant foliage and good cane growth are always associated with a sufficiency of nitrogen, and, considering the typical figure of 0.10 per cent. in the surface soil, nitrogenous fertilizer seems unnecessary until the vines show signs of weakening. This should not occur with a regular green manuring system. Any treatment which will increase the sugar-content and advance the ripening period is of primary importance, and from analogous instances it is highly probable that, while potash tends to promote this end, excess nitrogen tends to depress the sugar and put back the date of maturity. Despite the high content shown by analyses of the soils, potash may not necessarily be in a readily available form, and potash fertilizers deserve close attention in the experimental plots at present being conducted at Bungunyah.

The value of superphosphate as an essential fertilizer is emphasized, and it is considered that moderately heavy dressings of about 4 cwt. per acre on sultanas would give economic returns. In any case of intractability of surface soil or slow penetration of irrigation water, applications of gypsum or lime, whichever is the cheaper, would produce an improvement. Green manure crops in alternate rows annually, or at least two out of three years, should be a standard practice.

In the case of oranges, nitrogenous fertilizers are probably necessary, but the value of experimental dressings of other fertilizers should not be disregarded. The danger of frost damage seems sufficiently great to prevent any further planting of citrus, and the future of the settlement depends on the improvement of the sultana crop.

3. A Comparison of River-flat Soils of the Swan Hill District.

Soil surveys conducted within the region of Swan Hill have now defined four soil types having texture and profile characters in common. These occur on the river flats at Bungunyah, Murrabit, Beverford, and Speewa, and have been called Bungunyah clay, Murrabit clay, Beverford clay loam, and Swan Hill clay.* They are all heavy soils of alluvial origin. It would appear from Table 6, showing the reaction of the soils, that the Speewa flat was the most recently under the influence of floods from the Murray River, and that Beverford clay loam has been independent of river action for a longer period than the other soils.

* Beverford clay loam and Swan Hill clay are described in C.S.I. R. Bulletin No. 45, 1930, as Types 9 and 10 respectively.

On the triangle diagram (Fig. 5), illustrating mechanical analyses of soils, Murrabit clay and Bungunyah clay samples group well, and are shown to be very heavy. A comparison of the groups indicates a relationship between the Murrabit and Swan Hill clays, and between the Bungunyah clay and Beverford clay loam, and this concordance is supported by the pH distribution table. Summation curves (Fig. 6) illustrate in addition the absence of coarse sand in the Swan Hill clay and Murrabit clay soils. These curves have been drawn on averages for surface samples only, but adequately present the salient features of the soil types.

Results of soil surveys of these four river flats suggest that a close connexion would be obtainable between all similar flats in this district of comparable height above river level. The difference between the soils would lie mainly in reaction, depending on the time that has elapsed since the flat reached a level above the regular influence of high rivers.

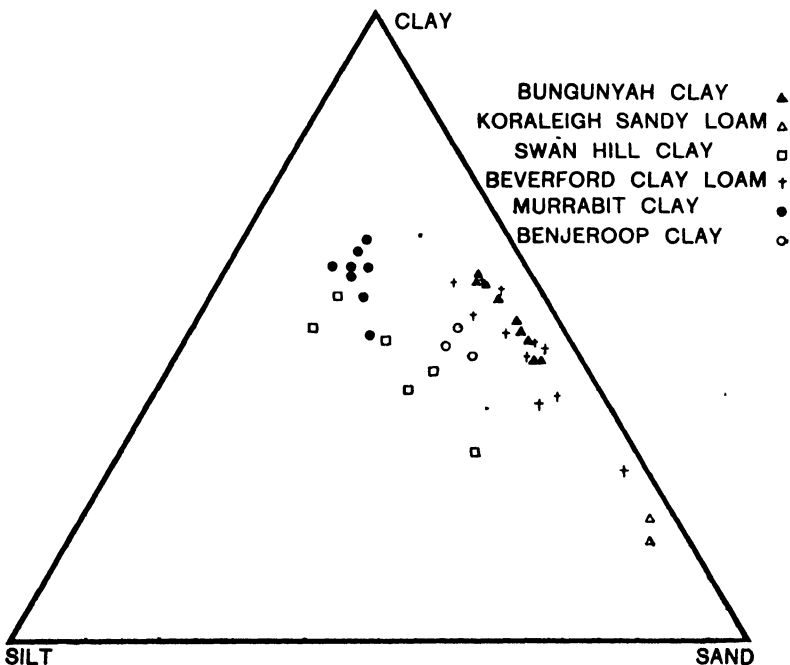


FIG. 5.—Distribution triangle illustrating mechanical analyses of soil types.

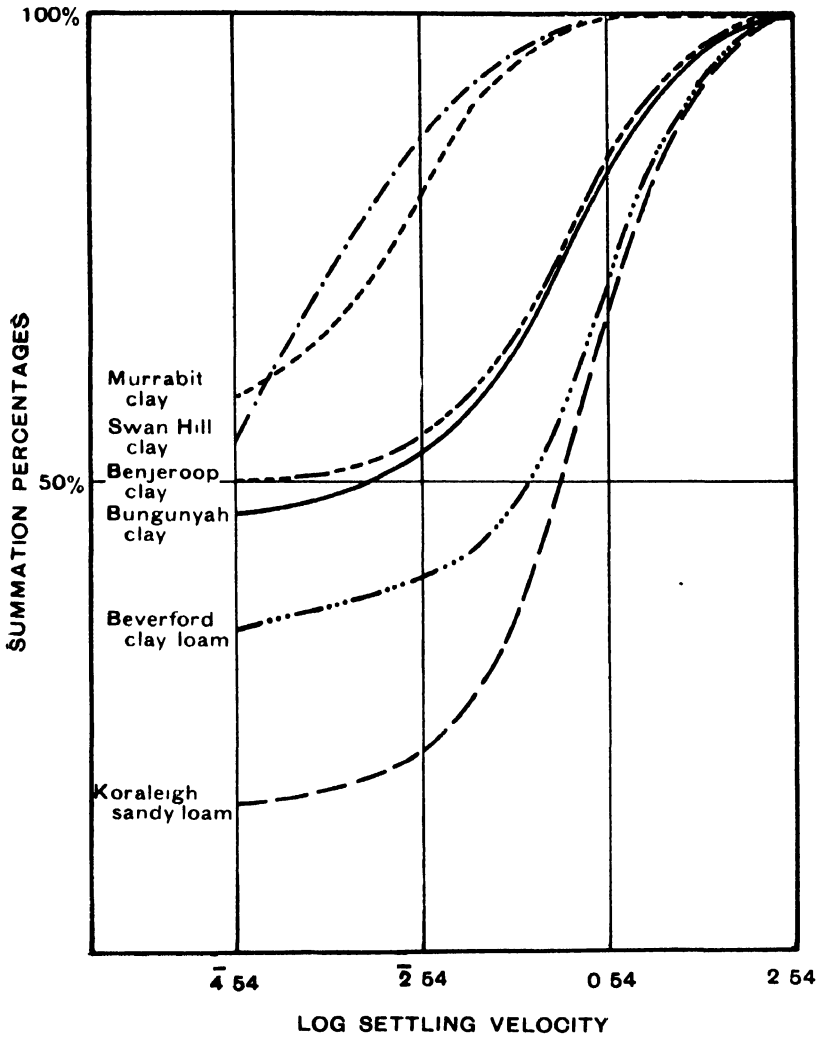


FIG. 6. -- Summation curves illustrating average mechanical analyses of surface samples of soil types.

The Sulphuring of Apricots.

By J. E. Thomas, B.Sc., B.Agr.Sc., B.V.Sc.*

Summary.

1. Under field conditions, the amount of SO_2 (sulphur dioxide) absorbed in drying apricots is closely related to the time of exposure to the fumes in the sulphuring chamber and to a minor degree to the amount of sulphur burnt.

2. The method of drying after sulphuring has an important influence on the SO_2 content in the resultant product; shade drying leads to a loss while sun drying appears to preserve the SO_2 content of the dried sample.

3. Heavy spraying or allowing to stand overnight before sulphuring appears to have little significant influence on the SO_2 content.

4. An estimate of the probable amount of SO_2 absorbed may be obtained in the field by applying an iodine test to the freshly sulphured fruit.

5. Under storage conditions a heavy loss in SO_2 occurs; there is reason to believe that the losses in moist packed fruit are heavier.

6. The re-processing of apricots is discussed. The rate of SO_2 absorption on resulphuring is shown to be correlated with the moisture content. Evidence is advanced in support of the contention that, in order to retain a satisfactory colour, re-processed fruit should contain not less than 10 grs. of SO_2 when packed.

1. Introduction.

In June, 1929, it having been found that some samples of Australian dried apricots contained more sulphur dioxide than the maximum amount permitted under British Health Regulations, a conference of representatives of the Council and of the State Departments of Agriculture concerned was held to formulate a programme of research into the whole problem. As a result the investigation of certain aspects of the problem was allocated to the Council. Work on these aspects was commenced in 1930, and the results of that season's investigations have already been published (this Journal 3: 161, 1930). During the subsequent year, studies were continued at Curlwaa, New South Wales, by the staff of the Commonwealth Research Station, Merbein, with the field assistance of Mr. McCutcheon, Horticultural Instructor, Department of Agriculture, New South Wales. The results of these studies are discussed below.

2. Experimental Methods.

The sulphur hoods used were those employed in the 1930 experiments,† and the procedure was, in all cases, very similar. During the trials, at half hour intervals, wet and dry bulb records were taken within the hoods. The thermometers were placed near view glasses about two-thirds up from the bottom of the chambers, and at the end distant from the entry of the sulphur fumes. Owing to the great variation in temperatures in different parts of the hood, however, the temperature records are of value for comparative purposes only.

The "Moorpark" variety of apricot was used and, unless otherwise specified, the fruit was sun dried. The methods of sampling and analyses employed were in accordance with the recommendations of

* An officer of the Commonwealth Research Station, Merbein.

† Lyon, A. V. "The Sulphuring of Apricots." This Journal 3: 161, 1930.

Mr. W. R. Jewell, Secretary to the Committee. For determination of moisture, the vacuum oven method* was found unsatisfactory, and a direct distillation method was used instead†. Determinations of SO_2 content in the dried fruit were made, by the official A.O.A.C. method, from 5 to 7 weeks after sulphuring.

3. Results.

(i) *Study of the Absorption of SO_2 .*—In order to control the rate of burn, the sulphur was burnt in a small pit outside the hood and the fumes admitted to the latter through a 3-inch pipe with an adjustable aperture. A number of additional exits which could be closed at will, and additional to those previously described by Lyon, were made, thus facilitating the alteration of the draught, and hence, the rate of burn of the sulphur. In practice, however, under field conditions, it was found difficult to burn a predetermined amount of sulphur in a given time.

The results obtained when sulphuring by burning the same amount of sulphur at different times are shown in Table 1. Those obtained when burning variable amounts of sulphur in a constant time are given in Table 2.

From the results detailed in Table 1, it will be seen that the amount of SO_2 absorbed by the fruit bears a fairly close relation to the time of exposure. An inspection of Table 2 discloses that wide variations in the amount of sulphur burnt have relatively little influence in the SO_2 content of the dried product under comparable conditions from the point of view of length of time of exposure. Under field conditions, there are other uncontrollable factors operating such as temperature and weather during the drying period (see next section). For this reason, comparisons of varying SO_2 content should be limited to any one experiment.

TABLE 1.— SO_2 ABSORPTION WHEN A CONSTANT AMOUNT OF SULPHUR WAS BURNT IN A VARIABLE TIME.

Expt. No.	Time of sulphuring. (hours)	Amount of sulphur burnt (lb./ton fresh fruit.)	Mean hood temperature. (Deg F.)	Mean shade temperature of atmosphere at the time (Deg F)	SO_2 content of dried fruit seven weeks later (grains per lb.)	Remarks.
1	3	3 26	110	90	6 5	Sun-dried one day, then shade-dried
	4	3 26	110	90	9 2	
	4½	3 26	108	90	6 3	
	5½	3 26	109	90	9 4	
2	3½	6 52	96	79	8 3	Sun-dried
	4½	6 52	96	79	10 2	
	5	6 52	96	79	11 5	
	5½	6 52	97	79	11 8	
3	3½	9 30	109	88	11 1	Sun-dried
	4½	9 30	101	88	12 7	
	5	9 30	106	88	14 9	
	6	9 30	101	88	16 1	

* "Methods of Analysis, A.O.A.C." 2nd Edn. 1925, p. 209.

† *Jour. A.O.A.C.* 9: 30, 1926.

TABLE 2.—SO₂ ABSORPTION WHEN VARIABLE AMOUNTS OF SULPHUR WERE BURNT IN A CONSTANT TIME.

Expt. No.	Time of sulphuring. (hours).	Amount of sulphur burnt (lb./ton fresh fruit.)	Mean hood temperature. (Deg. F.)	Mean shade temperature. (Deg. F.)	SO ₂ (grains per lb.).	Remarks
1	4 $\frac{1}{2}$	1 47	88	74	5 9	Sun-dried
	4 $\frac{3}{4}$	1 47	87	74	6 2	
	4 $\frac{3}{4}$	2 58	87	74	7 0	
2	4 $\frac{1}{2}$	3 07	101	83	7 9	Sun-dried
	4 $\frac{3}{4}$	3 89	100	83	8 1	
	4 $\frac{3}{4}$	4 51	104	83	8 3	
3	4 $\frac{1}{2}$	2 75	108	83	5 1	Sun-dried for one day then shade-dried
	4 $\frac{3}{4}$	6 51	109	83	7 1	
4	4 $\frac{1}{2}$	8 98	110	91	10 5	Sun-dried
	4 $\frac{3}{4}$	9 00	101	91	9 7	
	4 $\frac{3}{4}$	9 10	101	91	10 4	
	4 $\frac{3}{4}$	11 30	102	91	11 6	
5	4 $\frac{1}{2}$	7 46	109	92	7 4	Sun-dried for one day then shade-dried
	4 $\frac{3}{4}$	9 37	108	92	9 1	
	4 $\frac{3}{4}$	12 63	109	92	8 8	
6	4 $\frac{1}{2}$	5 49	108	90	11 0	Sun-dried
	4 $\frac{3}{4}$	6 34	109	90	14 0	
	4 $\frac{3}{4}$	6 77	110	90	11 6	
	4 $\frac{3}{4}$	8 49	110	90	13 8	
7	4	4 00	98	94	9 6	Sun-dried
	4	7 00	107	94	13 2	

NOTE.—With the exception of Experiment 1 in Table 2, the samples obtained from the experiments were of good commercial quality

During the tests detailed in Table 2, a number of samples of gas were aspirated from the atmosphere in the hood and examined for SO₂ concentration. This was found to fluctuate widely in different parts of the hood ranging from 0.20 per cent. near the entry of the sulphur fumes, 0.05 per cent. along the side, and 0.10 per cent. near the exit. A number of analyses were made of samples from comparable hoods burning varying amounts of sulphur, and, as was to be expected, it was found that the SO₂ concentration tended to increase as the rate of burn increased. Under current field methods of burning sulphur, using the "open" system, the concentration of SO₂ is relatively low, and, in such cases, the hood concentration does not appear to be a major factor controlling absorption. It would appear, however, from the results obtained by Chase, Church and Sorber* in California, that, when the gas concentration is kept at much higher levels (at from 1 to 15 per cent.), the concentration then becomes a prime factor in determining the amount of SO₂ retained.

* Chase, Church, and Sorber. "Large Scale Experiments in Sulphuring Apricots." *Jour. Ind. Eng. Chem.* 22: 1317, 1930.

(ii) *Sun Versus Shade Drying*.—Experimental work carried out in South Africa* tends to show that shade drying after sulphuring results in a reduction in SO_2 content. In the following tests, immediately after sulphuring, four trays were stacked in the sun. After one day's sun exposure, the top tray No. 1 was taken off, thereby exposing No. 2. On the second day, No. 2 was removed, and on the third day No. 3, thereby exposing No. 4. Owing to the very favorable weather conditions, the drying rate was particularly rapid. The results are given in Table 3.

TABLE 3.

No. of Tray.	Method of Drying	SO_2 content in grains/lb			
		Experiment No			
		1.	2.	3.	4.
1	Wholly sun-dried	10 1	11 4	12 6	11 9
2	One day's shade-drying—then sun-dried ..	8 2	8 9	9 9	10 1
3	Two days' shade-drying—then sun-dried ..	7 9	6 5	8 5	8 8
4	Three days' shade-drying—then sun-dried ..	7 6	6 4*	8 0	6·8*

* Wholly shade-dried.

The samples were graded in terms of colour and, in all four cases, the brightest were those wholly sun-dried, and the dullest the shade dried. The differences were not sufficiently great to have any commercial significance, although a greater diversity of colour might possibly have been obtained under less favorable drying conditions. It is apparent that the shade drying results in a very considerable diminution of SO_2 content and is, therefore, an easy and convenient method of treating fruit suspected of being over-sulphured. These results offer a partial explanation, at least, of anomalies noted in other experiments, for the weather during the drying period may profoundly control the SO_2 content.

(iii) *Influence of Spraying*.—In the report of the 1929-30 experiments carried out at this Station, it was concluded that light spraying with water or a 2.5 per cent. salt solution had little significant effect on the absorption of SO_2 . In a recent bulletin by Nichols and Christie†, it is stated that spraying tends to depress the absorption of SO_2 . On the other hand, Anderson (loc. cit.) presents some experimental work which indicates an increase in SO_2 content after moistening. For these reasons, some of the 1929-30 experiments were repeated. In each case, the samples "sprayed" were freshly cut and heavily sprayed.

* Andersen. "Sulphur Dioxide in Dried Fruit." Union of South Africa, Department of Agriculture, Science Bulletin 84 (1929).

† "Drying 'nt Fruits." Cal. Agr. Expt. Sta. Bull. No. 485 (1930).

The results are given in Table 4.

TABLE 4.

Position of tray in chamber.	Expt. 1.	SO ₂ content (grains/lb.).	Expt. 2 treatment.	SO ₂ content (grains/lb.).	Expt. 3 Control.	SO ₂ content (grains/lb.).
Top Guard	9 ..	..	..	..	..	9 5
8	Sprayed	9 5	Sprayed	6 3	Freshly cut. All trays	7 9
7	Cut 17 hrs.	9 6	Cut 17 hrs.	6 6		9 4
6	Freshly cut	9 4	Freshly cut	5 3		10 0
5	Freshly cut	7 7	Freshly cut	4 9		10 4
4	Cut 17 hrs.	10 7	Cut 17 hrs.	6 1		10 3
3	Sprayed	9 2	Sprayed	6 5		9 7
Bottom Guard	2					
Means	..		..	6 4		
	Sprayed	9 4	..	6 4		
	Cut 17 hrs.	10 2	..	6 7		
	Freshly cut	8 5	..	5 2		

The results of moisture determinations made on samples cut $\frac{1}{2}$ -in. parallel to the cut surface were as follows:—

Freshly cut	..	86.4 per cent.
Cut 17 hours (overnight)	..	86.3 " "
Sprayed	..	90.1 " "

The sprayed samples looked brighter and more attractive when removed from the sulphuring chamber, but little if any difference was discernible in the dried samples some 5 weeks later.

From the data presented in Table 4, it does not appear that spraying the fresh fruit or allowing it to stand overnight have any marked effect on either the SO₂ content or the ultimate colour.

(iv) *Application of an Iodine Test to the Freshly Sulphured Apricot.*—It was suggested by Mr. W. R. Jewell that an iodine test might act as a reliable field guide to the amount of SO₂ ultimately retained in the dried sample. Immediately after sulphuring, a composite sample was selected from the trays, the pulp expressed, and strained through muslin. Twenty-five mils. of the pulp were then titrated with N/10 iodine solution using starch as indicator. A blank determination was carried out with fresh un-sulphured apricots. The correction thus obtained varied between 0.25–0.50 mils. of the iodine solution. This test was applied to all the experiments, but in the light of the evidence obtained from the shade drying trials, only the results from samples which were wholly sun dried were used to plot a graph. Although a fairly wide scatter of points was obtained, the correlation co-efficient between the iodine figure obtained on fresh fruit, and the SO₂ content of the sun-dried product was sufficiently high to render the titration figure of value ($r = .61 \pm .14$). For samples containing more than 6 grains of SO₂ per lb. the most probable value could be estimated from the iodine test by use of the following:—SO₂ grains/lb. = mils N 10 iodine—2.0.

(v) *Storage Trials.*—The following table sets out the changes in SO₂ which occurred in samples of dried apricots stored at Merbein.

TABLE 5.

Date.	Time after sulphuring.	SO ₂ content (14—17 per cent. moisture).			
		Sample No.			
		1.	2.	3.	4.
22.2.30 ..	5 weeks ..	10·3	10·7	27 7	17·8
1.3.30 ..	6 weeks ..	9 3	11 3	24 3	n.d.
15.3.30 ..	2 months ..	7 9	10 1	25 0	17 0
15.4.30 ..	3 months ..	8 4	9 7	26 4	15 4
15.7.30 ..	6 months ..	6 1	9 5	21 7	12·5
15.10.30 ..	9 months ..	6 3	8 4	21 6	11·6
15.1.31 ..	12 months ..	5 9	7 4	17 5	9 5

The difficulties of sampling bulk packages are responsible for some apparent discrepancies in the above table. It will be seen that storage losses (probably due to oxidation) are very considerable. There is some evidence to show (Section vi) that the losses in moist packed apricots are much greater than this.

(vi) *Reprocessing of Apricots.*—During recent years, a moist pliable apricot rather than a bright dry one has been in keener demand on the London market. In order to produce the former article, re-processing is a standard packing shed procedure in California and South Africa. After delivery, at the packing shed, the fruit is moistened either by steaming or immersion and is then re-sulphured. This latter step is there considered necessary in order to prevent excessive darkening of the moistened fruit.

By arrangement with the authorities of "Australia House," samples typical of dried apricots being sold on the London market were collected in June, 1931, and forwarded in sealed containers to Merbein for examination, the results of which are given in Table 6.

TABLE 6.

Sample.	Colour grade (Max. 5).	SO ₂ content. (grains/lb.)	Moisture content.
Californian—			
Extra Fancy Tilton ..	4½	5 2	} 19·5—21%
Fancy Tilton ..	4½	5 0	
Extra Choice ..	4½	8 1	
Choice ..	3½	2 5	
South African—			
Three Diamond Royals ..	3½	5·7	} 21 1—23%
Two Diamond Royals ..	3	4 8	
Australian—			
Four Crown ..	5	6 6	} 16·0%
Three Crown ..	4	6·6	
One Crown ..	3½	3·2	

The Australian apricots contained approximately 5 per cent. less moisture than the Californian and South African samples.

In Australia, however, owing to the fact that the apricots, when delivered at the packing sheds, contain a higher SO_2 content than similar Californian fruit, it might be expected that some modification of procedure might be required to produce the more pliable and moister fruit in question.

In order to determine whether re-sulphuring might result in an increase in the SO_2 content above the statutory limits, tests were carried out to determine the absorption of SO_2 on re-sulphuring. From the results which are given in Table 7 below, it was found that the amount absorbed was related to the moisture content of the fruit (increasing with that content).

TABLE 7.

Sample No.	Moisture content.	SO_2 content after three hours' re-sulphuring.
	Per cent	(grains/lb.)
1	22	9.9
2	25	11.5
3	32	14.0
4	36	14.1
5	44	13.1

(NOTE.—The initial SO_2 content of the bulk samples was 8.1 grains/lb.)

(vii) *Storage Tests*.—Over-sulphured fruit may be reduced in SO_2 content by treatment with oxidising agents of which hydrogen peroxide and sodium hypochlorite solutions have been used. A series of sodium hypochlorite solutions containing from 0.1 to 0.5 per cent. of available chlorine were prepared and in these the dried apricot samples were immersed for 15 minutes. By this method a series of samples with varying SO_2 contents ranging from 3 to 9 grains per lb. were obtained. Each sample was adjusted to a 20 per cent. moisture content, and half of each was re-sulphured. Representative samples were forwarded to London and Melbourne in April, 1931, and returned at the end of the year. All showed a considerable colour deterioration which was greater in the case of those returned from London. Only those with the original sulphur dioxide content of 9 grs. or more of SO_2 retained a colour suitable for the trade. Typical losses in SO_2 content are shown below:—

TABLE 8.

Sample No.	Treatment.	SO_2 content after treatment as above in April, 1931	SO_2 content in December, 1931.		
			Merkein.	Melbourne.	London.
1	Re-sulphured ..	7.5	4.1	1.7	1.1
	Not re-sulphured ..	5.0	1.9	0.7	0.9
2	Re-sulphured ..	9.8	3.3	7.3	2.5
	Not re-sulphured ..	8.2	4.0	3.4	2.9

(NOTE.—All figures are in grains per lb.)

On arrival, the moisture content of the London samples averaged 20 per cent., the Melbourne samples 18 per cent. There is a very considerable and irregular loss in SO_2 , which appears to be greater in the case of the London samples.

In a similar larger scale experiment, bulk samples were sent to London and returned while similar samples were retained in sealed containers in Merbein.

TABLE 9.

Treatment.	London samples.			Merbein samples.	
	SO_2 content.	Quality (Colour).	Moisture Content.	SO_2 content.	Quality.
	grains/lb.			grains/lb.	
1. Moistened to 20% moisture 8 grs./lb. SO_2	1 3	3	21 0	1 0	3½
2. As in 1, but re-sulphuring 11 grs./lb. SO_2	2 4	3½	23 5	4 9	3½
3. Control untreated 11% moisture 12 grs./lb. SO_2	..	..	..	2 6	4

Further samples containing 8 to 14 grains of SO_2 per lb. were stored at an approximate moisture content of 20 per cent. and, on later examination, it was found that at least 10 grs. per lb. at the outset were necessary in order to retain a suitable colour. In these tests, the apricots were moistened by short immersion in water at a temperature of approximately 180 deg. F. In general, re-sulphuring resulted in the production of a slightly brighter fruit. In considering these tests, it has been borne in mind that they are very severe, involving two sea voyages and an eight months' storage. Normally, Australian fruit is disposed of within a few months.

Various methods of re-processing for a moist pack have been employed. Steaming in special chambers is the standard method when re-sulphuring is employed. Immersion in hot water at 180 deg. F. is also practised. Another method employed is to treat the fruit with a cold 3 per cent. paraffin emulsion in a washing machine; this increases the moisture content, and also tends to assure a high degree of immunity from later infestation of dried fruit pests.

The Effect of a Soil Mulch on Soil Temperature.

By E. S. West, B.Sc., M.S.*

In a previous issue of this *Journal* (Vol. 3, p. 27, 1930), Mr. West discussed the effect of a soil mulch on the quantity of water lost from a given soil by evaporation. The report that follows is somewhat complementary to that discussion, and it is accordingly printed below.—Ed.

Summary.

The loose layer of soil at the surface caused by cultivation has a lower heat diffusivity than the compact soil. In the case investigated, it is deduced that the heat diffusivity was reduced to 0.17 of that of the original compact soil. This results in the soil temperature wave of cultivated soil being markedly damped, when compared with that of the uncultivated soil for any particular depth below the cultivated layer. In the cultivated layer itself, the temperature wave at the surface has a greater amplitude than the temperature wave at the surface of undisturbed soil, but at the bottom of the cultivated layer the amplitude is much less in the cultivated soil than at a similar depth in the uncultivated soil. The mean temperature during the summer months, down to a depth of 60 cms., was about 2° C. cooler in the cultivated soil than in the undisturbed soil.

1. Introduction.

It is to be expected that a soil mulch, that is, a loosely cultivated surface layer of soil, should have some effect on the soil temperature, as soil in a loose condition is obviously a poorer conductor of heat than compact soil.

The phenomenon of the conduction of heat through soil was investigated by Patten†; Keen and Russell‡ investigated the trend of the soil temperature at Rothamsted at 6 inches deep, and its relation and dependence on sunshine, wind, and other weather factors; and Taylor§, working in Egypt, investigated the daily and seasonal temperature wave at different depths and the relation between the waves at various depths.

The question of the effect of cultivation on the soil temperature, though of obvious importance, particularly under such conditions as the bare fallow of the Australian wheat farm, and in clean cultivated orchards, does not seem to have been investigated before, so that records have been kept at the Commonwealth Research Station, Griffith, of the soil temperature at different depths, both in cultivated and uncultivated soil, weed growth being prevented in both cases.

2. Experimental Procedure.

Two adjacent plots on uncultivated, undisturbed land, each 18 feet x 9 feet, were marked out. Thermometers were placed at depths 15 cms., 30 cms., and 60 cms. at each end of each plot, in positions 4½ feet from the ends and sides of the plots. The bulbs of a two-bulb Negretti and

* Officer-in-charge, Commonwealth Research Station, Griffith.

† Patten, H. E. "Heat Transference in Soils." U.S.D.A. Bur. Soils, Bull. 59 (1909).

‡ Keen, B. A., and Russell, E. J. "The Factors Influencing Soil Temperature." *Jour. Agric. Sci.* 11: 212-239, 1921.

§ Taylor, E. M. "Soil Temperatures in Egypt." *Jour. Agric. Sci.* 18: 90-122, 1928.

Zambra soil thermograph were also placed, one in the centre of each plot, at a depth of 15 cms., and the bulbs of a second similar instrument were placed at 30 cms. in the centre of each plot.

The thermometers were ordinary chemical mercury instruments about 17 cms. long, graduated from 0° C. to 60° C. in wide graduations, the 1° graduation being about 3 mms. long. This meant that the mercury column was rather sluggish, which was an advantage, as it prevented undue alteration while reading. In placing the thermometers in position, a hole was driven into the soil with an iron rod. The bottom part of the hole was formed by the use of a rod of smaller diameter and shaped at the end to the same shape as that of the thermometer. When placed in position, the bulb of the thermometer, therefore, fitted snugly into the soil. A casing of glass tube was then placed in the upper part of the hole to prevent soil falling into it. In the case of the 30 cms. and 60 cms. depths, glass rods were attached to the end of the thermometers by means of rubber tubing, to permit the ends and sides of the plots. The bulbs of a two-bulb Negritti and of the lowering of the thermometers to the correct depths. As the bulbs of the thermometers are about 15-17 mms. long, the holes were made of such depths that the centre of the bulb corresponded with the depths desired. The thermometers were read by quickly raising them until the mercury column was visible and noting its position. Readings were taken to 1-10th of a degree.

The 15 and 30 cms. thermometers were read twice daily at the times of the maxima and minima temperatures, but as the temperature wave at 60 cms. is so small, the temperature at that depth was read only once a day, at 9 a.m. The maximum temperature for any depth occurs at a definite time after the sun is in the meridian, and occurs at 6 p.m. for the 15 cms. and 10 p.m. for the 30 cms. The times of the minima temperatures depend on the time of sunrise and so varies throughout the year.* The time for each depth can be readily determined by the time of sunrise, but it was found more convenient to observe the time from the thermograph for the 15 and 30 cms. depths.

The plots were set up in June, 1929, and allowed to remain undisturbed until 22nd August, 1929, in order to allow them to settle down under the influence of the weather. The temperatures, however, were recorded. One plot was then carefully dug to a depth of 10 cms., and a fine mellow mulch was maintained thereafter. This caused the surface to rise 3 cms. Datum pegs had previously been put in, so that the original levels of both plots could be referred to, if desired.† After rains, the soil of the cultivated plot was stirred to maintain the mulch. Weed seedlings were plucked from the uncultivated plot as soon as they appeared. In the case of the cultivated plot, the stirring of the soil after heavy rains kept down the weeds.

3. Discussion of Results.

Figs. 1 and 2 show typical soil temperatures for the 15 cms. and 30 cms. depths, respectively. It is to be noted that the wave in the cultivated plot has a slight lag and is greatly damped, compared with that in the uncultivated plot.

* Taylor, E. M., loc. cit.

† It is to be understood that the depth in the mulch plots refers to the depth from the original surface level before cultivation and not the depth from the new surface level.

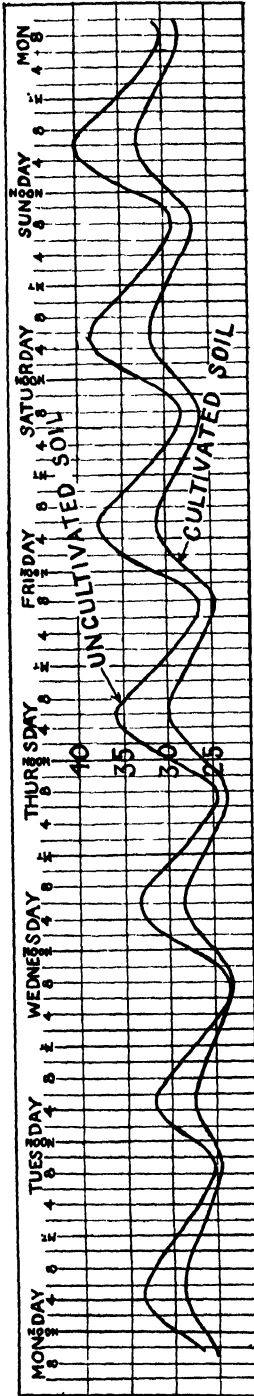


FIG. 1.—Soil temperatures 15 centimetres deep.

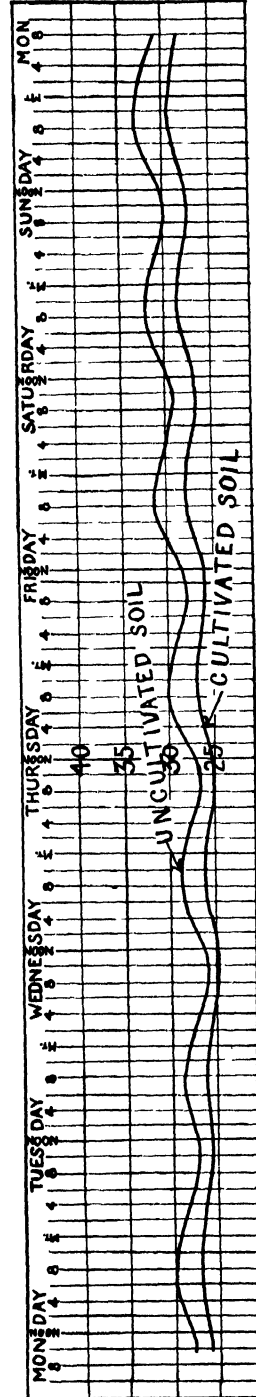


FIG. 2.—Soil temperatures 30 centimetres deep.

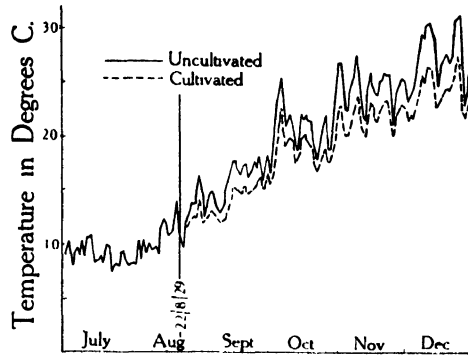


FIG. 3.—Daily mean soil temperatures at 15 centimetres.

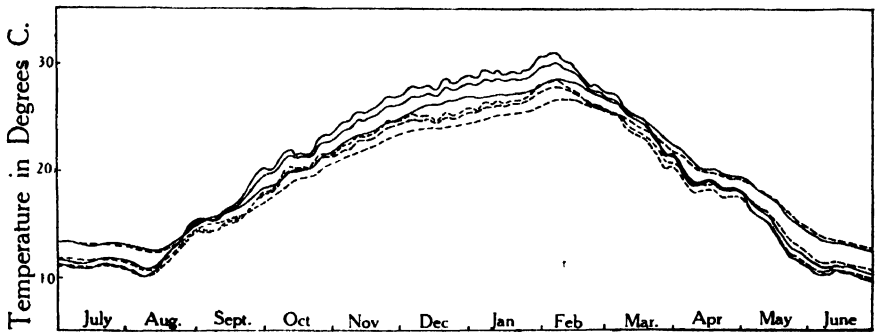


FIG. 4.—Smoothed curves showing trends of mean soil temperatures from 1st July, 1930, to 30th June, 1931.

The mean daily temperature* recorded by each thermometer was plotted throughout the period of the experiment. At all times, the graphs of the duplicates ran close together, though those for the different depths and in the cultivated and uncultivated soils diverged. The mean daily temperatures determined by the thermometers also accorded with the data obtained from the thermographs, so that the data submitted can be taken as an accurate record.

Fig. 3 shows the mean daily temperatures for 15 cms. depth for both the cultivated and uncultivated plots, for a period in the spring. The excessive fluctuations which rather obscure some of the properties of these curves are smoothed out in Fig. 4, which shows smoothed curves for a typical twelve-month period.† In Fig. 4, the ordinate for each day is the mean temperature for the three-week period, of which that day is the median. That is, to obtain the ordinate for the smoothed curve for the 15 cms. of the mulch plots for 11th March, the arithmetic mean of the mean temperatures for each day of the period from 1st to 21st March inclusive was found. Each daily mean is the mean of the mean temperatures determined from the two chemical thermometers and the thermograph, so that, $21 \times 3 \times (\text{max.} + \text{min.}) = 126$ readings are used in obtaining each ordinate in Fig. 4.

Considering, first of all, the graphs for the uncultivated plot, all the well-known features of the seasonal temperature wave are readily recognized, namely, the increasing temperature gradient with depth in the winter, the decreasing gradient in summer, and the crossing over of the graphs in March and late August, when the mean daily temperatures at these depths are uniform. The damping out and lag of the lesser fluctuations in temperature with depth is also evident.

Considering the effect of the soil mulch on the trend of the soil temperature, it is seen from Fig. 3 that, immediately after the soil mulch was made on 22nd August, the soil began to warm up more quickly in the uncultivated soil than in the cultivated soil at the three depths recorded, so that, during the summer months, the temperature at the 15 cms. depth is usually about 3° C. warmer in the uncultivated soil than in the cultivated soil, and even at the 60 cms. depth, the uncultivated soil is about 2° C. warmer than the cultivated soil. During the cool changes in the summer, the differences in temperature are inclined to be a little less, due to more rapid cooling of the uncultivated soil. In the autumn, the uncultivated soil cools more rapidly than the cultivated soil, so that, in the beginning of the winter, i.e., about May or June, the temperatures are the same in both cultivated and uncultivated soils. During the winter, there is a tendency for the temperature on the cultivated soil to fall below that of the uncultivated soil, but this tendency is largely obliterated by the winter rains. The effect of heavy rains is to cool the surface layers of the soil, and, at the same time, to bring the cultivated and uncultivated soils to approximately the same temperature. As the capacity for heat of the water retained by soil after a heavy rain is two or three times as great as that of the dry soil, the comparatively small differences in temperature of the cultivated and uncultivated soils are largely swamped out. The large cooling effect of the evaporation of water from the surface after the rain

* The arithmetic mean of the maximum and minimum daily temperature is taken as the daily mean temperature. Actual calculations from the thermograph records for both the 15 and 30 cms. depths showed that this was in fact a very close approximation of the true daily mean.

† Data are available for a period of three years, but those for the other two years are similar in all essential details to those for this twelve-month period.

would also tend to swamp the original differences in temperature. For the three years, the mean temperatures for the three summer months, namely, December, January, and February, were as follows:—

—				Uncultivated Soil.	Cultivated Soil.
Depth 15 cms.	..	..	..	30.10° C.	27.31° C.
„ 30 cms.	..	..	..	29.17° C.	26.92° C.
„ 60 cms.	..	..	..	27.73° C.	25.85° C.

Similar data for the six months, October-March inclusive, were—

—				Uncultivated Soil.	Cultivated Soil.
Depth 15 cms.	..	..	..	27.23° C.	24.81° C.
„ 30 cms.	..	..	..	26.42° C.	24.53° C.
„ 60 cms.	..	..	..	25.58° C.	23.77° C.

As there is such a marked difference in the soil temperature at the depth of 60 cms., it is quite obvious that cultivation must have a big effect on the soil temperature to much greater depths, in fact, it appears evident that the temperature to the total depth of soil of chief agricultural interest, i.e., the depth to which the greater proportion of the roots of most plants penetrate, is appreciably affected by the loose layer of soil created by cultivation. Whether this is an advantage, or otherwise, to plants, probably depends upon the type of plant grown, as the maximum daily temperature at 15 cms. seldom rises about 40° C., even in the uncultivated soil, which is about the optimum soil temperature for many summer growing plants. It is improbable, however, that the soil temperature effect of cultivation would have an appreciable direct effect on the plant.

In order to examine, in more detail, the insulating effect of the mulch, a further set of thermometers was set up in two plots, immediately adjacent to the original plots. One plot was stirred to a depth of 10 cms. and a line of thermometers was placed in each plot, 5 cms. apart and every 2 cms. in depth in the uncultivated from 2 to 24 cms., and in the cultivated soil from 0 to 22 cms.* Readings were taken every two hours from 6 a.m., 24th February, 1932, to 10 p.m., 25th February, 1932, the thermometers having been set up a day or two before this period. When placed in position, the mercury column was visible in the thermometers to the 12 cms. depth, so that these were placed in position without a glass casing. In the case of the lower depths, a glass casing was used near the surface.

As the bulbs of the thermometers are 2 cms. long, the reading of the thermometers placed at any particular depth, for example, 10 cms., is actually due to a kind of mean temperature for the depth 9-11 cms., rather than the temperature at the 10 cms. point, but for the purpose of the following comparison this would not seem to affect the issue.

Figs. 5 and 6 show the series of temperature waves obtained by plotting the temperature against the time for each depth, in the uncultivated and cultivated plots, respectively. A comparison of these figures

* As the surface of the cultivated soil rose 3 cms. in height, the thermometer at depth 0 cms. though 10 cms. above the undisturbed soil, was 3 cms. below the new surface of the stirred soil.

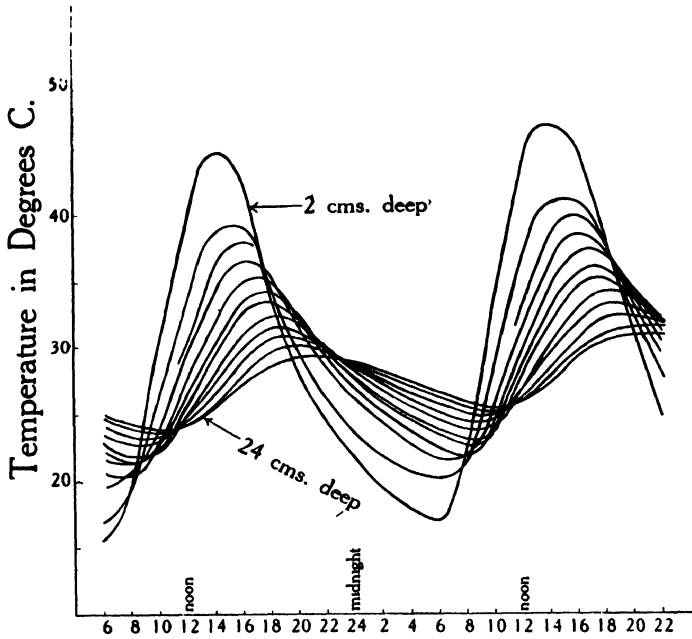


FIG. 5.—Temperature-time curves for different depths in uncultivated soil.

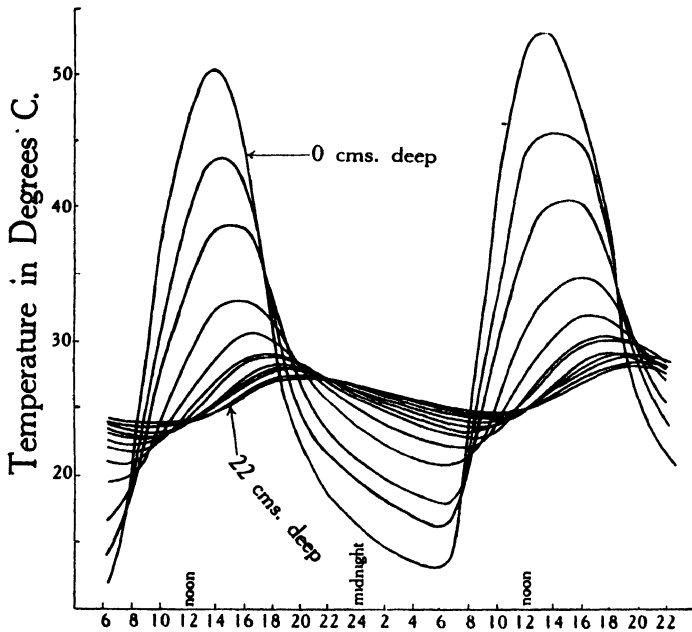


FIG. 6.—Temperature-time curves for different depths in cultivated soil.

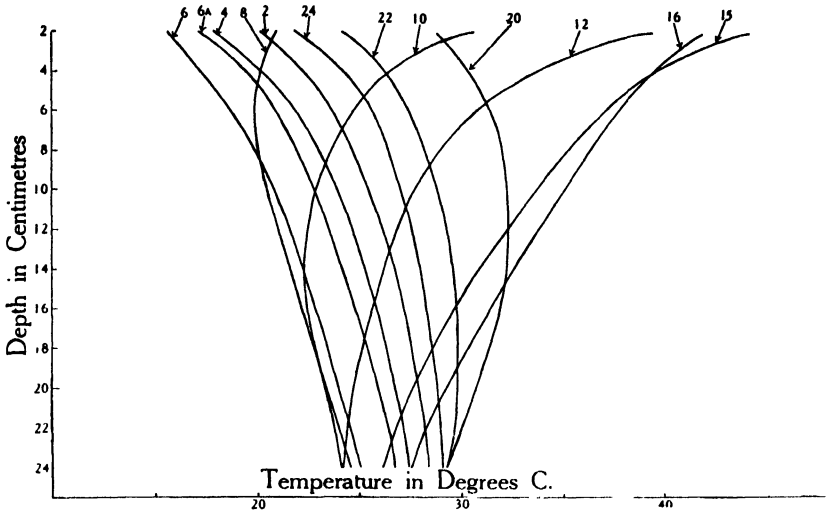


FIG. 7.—Temperature-depth curves from 6 a.m., 24th February, 1932 (6), to 6 a.m., 25th February, 1932 (6A), in uncultivated soil.

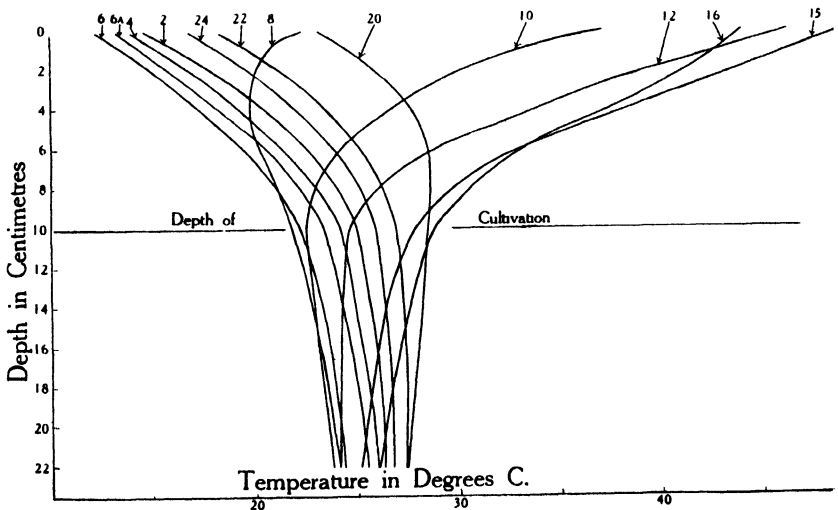


FIG. 8.—Temperature-depth curves from 6 a.m., 24th February, 1932 (6) to 6 a.m., 25th February, 1932 (6A), in cultivated soil.

at once shows that the diurnal temperature wave at the surface of the cultivated soil has a much bigger amplitude than that of the uncultivated soil. That is, that the surface of the cultivated soil gets warmer during the day and colder during the night than that of the uncultivated soil.† However, owing to the difference in heat diffusivity of the cultivated layer to that of the compact soil, the wave is damped out with depth much more quickly, as illustrated by the bigger spaces between successive maxima and minima in the first 10 cms. of cultivated soil. As a result of this, the wave at the 10 cms. depth (bottom of mulch) has a much smaller amplitude than that at the same depth in the uncultivated soil. The loose mulch has a lower diffusivity of heat than the compact soil, so that, on warming up the surface, heat moves down more slowly when the surface is cultivated, and the surface, therefore, becomes warmer than is the case in compact soil. During the night, heat moves more slowly to the surface from below to replace heat lost by radiation, so that, the surface cools more on the cultivated soil than on the uncultivated soil. However, due to the lower diffusivity of the soil, the wave is damped out much more quickly when the surface is cultivated. These relationships are made evident in considering the ratio of the amplitudes of the successive temperature waves as in Table 1.

TABLE 1, SHOWING THE RATIO $\frac{\text{AMPLITUDE AT DEPTH } x \text{ CMS.}}{\text{AMPLITUDE AT DEPTH } x + 2 \text{ CMS.}}$
For Uncultivated and Cultivated Plots.

Depth in Centimetres.	Uncultivated.			Cultivated.		
	Amplitude.	Ratio.	Mean Ratio.	Amplitude.	Ratio.	Mean Ratio.
0	36.6		
2	27.6			28.0	0.76	
4	19.2	0.70*	0.87	20.5	0.73	0.71
6	16.6	0.86		12.4	0.61	
8	15.0	0.90		8.7	0.71	
10	12.9	0.86		6.4	0.73	
12	11.4	0.88	0.83	5.7	0.89	0.87
14	10.2	0.89		4.5	0.79	
16	8.4	0.81		4.0	0.89	
18	6.8	0.81		3.6	0.90	
20	5.5	0.81		3.1	0.86	
22	4.8	0.87		2.7	0.87	
24	3.7	0.77				

NOTE.—* The thermometer at 2 cms. depth was so close to the surface that the bulb was almost visible. Probably the mercury was partly heated and cooled by direct radiation, which caused an exaggerated amplitude for the 2 cms. wave (Fig. 5), which would tend somewhat to depress this ratio.

† This is manifest in frosty weather when it will be observed that frost appears on cultivated land before it appears on bare, uncultivated soil.

If the soil were uniform with respect to conductivity and specific heat throughout its depth, these ratios should be constant. It is to be seen that the ratios in the uncultivated plot and undisturbed soil of the cultivated plot are approximately constant at 0.85. In the case of the cultivated portion, however, the ratio is approximately constant at 0.71, which means that the diffusivity, i.e., the ratio "conductivity divided by specific heat" is less in the cultivated portion. From these ratios, it is possible to obtain some idea of the influence that the cultivation had on the diffusivity of the surface 10 cms. of this soil:—

Consider the two equations:—

$$k = \frac{\lambda^2}{4\pi\tau}$$

and
$$\frac{\theta_2}{\theta_1} = e^{-\frac{2\pi(x_2 - x_1)^*}{\lambda}}$$

where k = the diffusivity

$\frac{\theta_2}{\theta_1}$ = the ratio of the amplitudes of the temperature waves at depths x_1 and x_2 .

τ = time period of temperature wave

λ = wave length.

Combining the two equations

$$\log \frac{\theta_1}{\theta_2} = -(x_2 - x_1) \sqrt{\frac{\pi}{\tau k}}$$

$$\text{putting } \log \frac{\theta_1}{\theta_2} = r$$

$$\text{then } k_m = k_c \frac{r_c^2}{r_m^2}$$

where the subscripts c and m refer to the compact and cultivated (mulch) soils, respectively.

Using the figures obtained above for the ratios, viz., 0.87 for that of the compact soil and 0.71 for that of the cultivated soil, it appears that the diffusivity of the cultivated soil is 0.17 times that of the compact soil.

The effects of the cultivated layer are well brought out in Figs. 7 and 8, which show the temperature-depth curves for different times in both the uncultivated and cultivated soils. These series of curves may be considered to sweep from one extreme position at the time 6 o'clock to the other extreme position at 15 o'clock† and then back again, but during the morning, as at 8 a.m., the soil is still cooling at the lower depths, while warming near the surface, as is evident from the positions of the 6 and 8 o'clock curves, while during the afternoon the soil is cooling near the surface and still warming up below, as is evident from the 15 and 16 o'clock curves. It may be noted that when two curves representing consecutive time intervals cross, it represents a maximum

* Keen, B. A. "The Physical Properties of the Soil." Longman, Green, and Co., pp. 310-311 (1931).

† Actually, the maxima at the surface occurred at 2 p.m. = 14 o'clock, but, unfortunately, this reading was missed. It is seen that the curve 15 o'clock has already begun to sweep back.

in the temperature wave at that depth (Figs. 5 and 6), if the curve representing the later time crosses the other from left to right going down, and a minimum if it crosses from right to left going down.

Where the temperature depth curves are vertical it means that the temperatures are uniform at these depths at this time, as in the 12 o'clock curve (Fig. 8) from depths 12 to 22 cms. (see also the curves for these depths at 12 o'clock in Fig. 6). The distance between the extreme curves at any particular depth shows the amplitude of the soil temperature wave at that depth, and the slope of curves at any depth shows the temperature gradient at that depth and time. Keeping this in mind, the effect of the stirring of the soils is at once evident, by comparing Figs. 7 and 8. The amplitude of the temperature wave is greater at the surface of the cultivated soil than that of the uncultivated soil, but the temperature gradients at the times of the minimum and maximum surface temperatures are much steeper in the cultivated soil than in the uncultivated soil, so that, at the depth of 10 cms. (depth of cultivation) the amplitude is much smaller in the cultivated soil than that in the uncultivated soil. The curves in Fig. 8 consist of two portions, that above the 10 cms. depth (depth of cultivation), where the slopes are greatest, and that below the 10 cms. depth, where the slopes are small. Breaks in the curves occur at the 10 cms. depth.

4. Conclusion.

In this experiment, the temperatures in a bare undisturbed soil are compared with those in a cultivated soil. Where vegetation is allowed to grow, the conditions would be different, and the effects would largely depend upon the type of vegetation, whether green or dry, abundant or sparse, &c., but in general one would expect the same type of effect as with the cultivated layer of soil, viz., the damping of the daily and seasonal wave, causing a lower summer soil temperature, compared with that of the bare undisturbed soil.

Radio Research Board: Fourth Annual Report (for Year ended 30th June, 1932).

The Radio Research Board of the Council is constituted:—Professor J. P. Madsen (University of Sydney), Chairman; Mr. H. P. Brown (Director-General, Postmaster-General's Department); Electrical-Commander F. G. Creswell (Department of Defence); and Professor T. H. Laby (University of Melbourne). Its previous annual report was published in this *Journal* (Vol. 4, No. 4, November, 1931).—Ed.

1. General.

Throughout the period under review, the work of the Board has been concentrated on two main lines, namely:—(i) fading and Heaviside Layer work, and (ii) atmospheric.

The staff of the Board has declined still further, Dr. L. G. H. Huxley resigning in September, 1931. This loss of staff, however, has been offset by the services of two University research workers being kindly made available to the Board by the co-operation of the authorities concerned. These students are Mr. H. B. Wood, of the University of Sydney, and Mr. W. J. Wark, of the University of Melbourne. Towards the close of the year, Professor Madsen and his staff were able to complete the erection of an experimental emitting station in the P. N. Russell Engineering School of the University of Sydney. The transmitter is capable of delivering a power of approximately 1,000 watts into the aerial, and has been specially designed for the fading and Heaviside Layer work of the Board.

2. Work on Fading and the Heaviside Layer.

Throughout the period under review, the studies of fading and the Heaviside Layer have been continued in Victoria and in New South Wales.

In the previous report, it was mentioned that some work was in progress on the method proposed by Dr. Martyn for estimating the height of the Heaviside Layer at various times and under various atmospheric conditions. For various reasons, progress has been delayed, but the investigations are now being continued.

The classification of the different types of fading that occur naturally is obviously of considerable importance from the point of view of the systematic development of means of mitigating the troublesome effects of the phenomenon in question. Work of this nature done to date has resulted in a considerable amount of information regarding conditions of radio reception in Australia. Much of this information is contained in the Board's Report No. 4 (published as the Council's Bulletin 63). In Victoria, many observations have been made at distances up to 200 kilometres from the emitting stations (generally 3LO and 3AR), and some at much greater distances, the emitting stations in these cases being located at Sydney, and the observations being made at Gembrook (Vic.).

The apparatus used for observations on the Victorian stations consisted of a simple type of valve voltmeter, and a continuous photographic recorder. Observations were made simultaneously on two separate aerial systems, one a loop aerial, and the other a vertical aerial. It was found possible to separate the two aerials by 20 or 30 feet without affecting the identity of the signal picked up. This greatly simplified the technique, since the separation was sufficient to prevent electro-magnetic coupling.

Observations at distances of 500 to 1,000 kilometres from the transmitting station have shown that two types of fading occur, namely: (i) slow fading of a regular period ranging from two to thirty minutes; and (ii) quick fading superposed on the slow fading, and of smaller amplitude, but of more regular period.

The results of the observations at distances up to 200 kilometres from the emitting station showed that fading was not entirely erratic in character. Three types of regularity were found:—

- (a) Slow fading of period one to five minutes, and having an amplitude such that the signal intensity ranged from less than half the steady day value to almost double that value.
- (b) Quick fading of period five to thirty seconds, and of amplitude less than half that of slow fading.
- (c) Periodic fading, which appears most often in the period from one or two hours after sunset, is of remarkably pure sinoidal form, and has a larger amplitude than quick fading.

Slow fading was found to be due to interference between the ground ray and a ray reflected from the lower Heaviside Layer. Quick fading was attributed to similar interference produced by the upper ionized layer, while the mechanism of periodic fading could not be analysed further than the fact that it was a lower layer phenomenon. In many cases, however, particularly at the nearer receiving sites, it was found that anomalous results were obtained. In these cases, the fading was not in phase on the two aerial systems. Moreover, it was repeatedly found that the height of the Heaviside Layer, as deduced from the angle of incidence of the down-coming wave, was definitely lower than that obtained by other methods of measurement, such as the Appleton frequency-change method. Only two possible explanations of these anomalies could be found, namely:—(i) imperfect conductivity of the ground, and (ii) lateral deviation of the sky wave, i.e., propagation on a plane other than the vertical plane through transmitter and receiver. Experiments were conducted over sea water, which has a considerably higher conductivity than soil, but the anomalies still persisted. It was, therefore, concluded by a process of elimination that there existed a considerable amount of lateral deviation of the sky wave.

Hitherto, it has been assumed by those investigating their propagation, that radio waves on broadcast frequencies are not deviated laterally, but the evidence on which this assumption is based is far from conclusive. Moreover, the theoretical work of Dr. W. G. Baker, whilst he was a member of the staff of the Radio Research Board, suggests that the asymmetry introduced by the earth's magnetic field might well be responsible for a lateral deviation of sky waves.

A method depending on the taking of simultaneous observations of natural fading on three aerial systems was accordingly developed to measure, among other things, this lateral deviation. As a result, clear evidence of the lateral deviation of the sky wave has been found. The method has been adapted to the frequency-change technique of Appleton, thus rendering it possible for observations to be made on all the constants of the down-coming ray, including its lateral deviation, irrespective of the degree of turbulence of the Heaviside Layer itself. This work will be undertaken, using the new experimental emitting station at the Sydney University.

Studies of the heights of the Heaviside Layer at various times, and of the polarization of sky waves after reflection from the Layer, have been continued. The results of this work, which was carried out mainly at Jervis Bay, have been published as the Board's Reports Nos. 2 and 3 (issued as the Council's Bulletins 59 and 60 respectively). It was found that the polarization of the down-coming rays at the time of observation—which was necessarily near sunrise—was fairly constant. This suggested—an assumption which was also to a certain extent supported by theoretical considerations—that such a condition of polarization might hold for other periods of the day or night, in which case it would be possible to control fading at moderate distances from the transmitter by balancing the abnormal component of the down-coming ray against the normal. Trials carried out at Liverpool, however, indicated that such conditions did not hold, and it was realized that the state of polarization of the down-coming rays at different times of the day required further investigation.

This work required a special technique, the development of which has been considerably helped by the fact that the studies of fading in Victoria have shown that the necessary different types of aerials could be used at the receiving site, provided they were suitably spaced. A method has accordingly been developed involving simultaneous observations on three different aerials at Liverpool. Special attention has been given to the sky wave and to its reception on different types of aerials. Already various novel properties of different types of aerials have been noted. For example, a short horizontal antenna was found to have marked directional properties, being rather better in this respect than a loop aerial.

3. Work on Atmospherics.

(i) *Equipment*.—In last year's report, a description was given of the method of observing atmospherics using two cathode-ray direction-finders, one located at Mt. Stromlo, near Canberra, and the other at Laverton, near Melbourne, the base line being approximately 300 miles. The two observers are able to communicate with short-wave remote-controlled transmitters working on 43 metres, so that directions of individual atmospherics can be observed simultaneously at the two stations, and their origins located by plotting the bearings. The work on those instruments has been carried out on wavelengths between 3,000 and 30,000 metres, but mainly on 3,000 metres, and mostly by day. In most cases, the intensities as well as the directions of the atmospherics have been observed.

Early in the present year, a new type of cathode-ray oscillograph (designed by von Ardenne) was installed at the Laverton station. Owing to its better focussing and brighter spot, more accurate observations of sizes and directions of atmospherics and of their characteristics can be obtained. Another such tube is being used at Laverton on an auxiliary receiver to give the intensities on 300 metres, or thereabouts, of atmospherics observed simultaneously on the cathode-ray direction-finder on 30,000 metres.

A continuous directional recorder for atmospherics, which was designed and constructed by the British Radio Research Board, has been in use at the Mt. Stromlo station for a year. This instrument uses a rotating loop aerial system, and the signals after amplification activate an oscillograph. The end of the oscillograph pointer carries a siphon pen which records on a paper chart on a rotating drum, and the arrangement of the amplifiers is such that each atmospheric received produces a vertical upward kick of the pen.

(ii) *Results*.—It was stated in last year's report that all the atmospherics observed appeared to be due to lightning strokes generally occurring in thunderstorms, and that atmospherics appeared to have much the same size at their origin, so that variations in the observed intensities were due mainly to attenuation in the paths. In other words, if we regard each atmospheric as being produced by a natural transmitter, then all these transmitters operate with the same order of power. These conclusions have been confirmed by all the more recent work.

The average intensity of a source of atmospherics has been taken as the mean of a number of typical individual atmospherics in it, and when these mean intensities on 3,000 metres for a number of sources are plotted against the distance of the corresponding sources as located by the direction-finders, the points are found to lie closely along a mean curve representing the variation of intensity with distance from 50 to 1,500 miles. The most marked deviations from the curves are for those cases in which the transmission path is (i) over heavily-wooded ranges and the attenuation is exceptionally great, and (ii) over sea, where, as would be expected, the attenuation is least.

The observations have indicated that for a given atmospheric, the intensity observed on a receiver of given low-frequency response is to a first approximation proportional to the wavelength to which the receiver is tuned. In addition to this, the attenuation is much greater on short wavelengths than on long. This would mean that, other conditions being equal, the longer the wavelength to which a receiver is tuned the more the interference from atmospherics. As mentioned previously, however, observations are now in progress to extend the knowledge of the intensities to the shorter wavelengths of the broadcast band using an auxiliary receiver on 300 metres.

A year's charts from the recorder have been analyzed and considered in conjunction with (i) the cathode-ray direction-finder observations, (ii) meteorological reports, particularly of thunderstorms in and near Australia, and (iii) Brooks's charts of the distribution of thunderstorms over the earth.

The use of the cathode-ray direction-finder observations on shorter wavelengths down to 3,000 metres has enabled the nearer sources to be distinguished from the distant ones. It has been found that the sources fall into two fairly distinct types:—(i) *regular*, which occur in the same direction at the same time almost every day over several months of the year; and (ii) *irregular*, which show no marked period of recurrence in either direction, time, or duration.

The combined evidence of direction, diurnal variation, and seasonal variation, and of observations of close sources, establishes quite decisively that the regular sources are in the tropical areas of great thunderstorm activity.

In the local summer months, September to March, one of these very active areas exists in the north of Australia, so that it has been possible to observe with the direction-finders the sources (i.e., the most active centres) there, and to record the intensities and frequency of occurrence of atmospherics in such sources, the latter being generally at least 60 per minute, giving an almost continuous disturbance in a receiver. This area is naturally the most serious as regards interference with radio reception in Australia. The area includes New Guinea and Java and the surrounding islands, and is active during the afternoon and evening, the maximum of activity moving westward with the sun. The other main source during this season is in tropical Africa south of the Equator. This is the most intense thunderstorm area in the world.

From April to October, there is little day-time activity to the north, but a fairly strong evening source in the direction of the Malay Archipelago and southern Asia. The night source from Africa is very prominent, but it has now moved to mainly north of the Equator. A further source becomes apparent just before dawn in the direction of Central Europe and Central America (great circle). Considerations of time and thunderstorm activity suggest that this is probably mainly from the American area, the atmospherics taking the longer night path. This source is no longer apparent after sunrise, probably owing to unfavorable transmission conditions.

The irregular sources again fall into two main classes:—(i) Distant sources in directions between N and E, probably due to thunderstorms over the tropical ocean and islands; and (ii) sources occurring within or close to Australia in sub-tropical latitudes and associated with areas of low barometric pressure. The frequency of occurrence in this last type of source is much less than for the regular ones (partly, but not wholly, due to the smaller area) being generally less than 30 per minute, and may be as low as one or two in five minutes for depressions over the sea to the south.

The sources in the Tasman Sea are particularly reliable as indications of weather conditions, for practically every depression in this region in lats. north of 40° S. has atmospherics associated with it by day. In the Australian Bight, the atmospherics from depressions of equal intensity are fewer than in the Tasman, but they give useful indications of the presence of depressions which are too far south for observations by land stations or ships, so enabling more accurate forecasting of weather in Victoria and Tasmania.

All the evidence obtained as a result of the investigations to date supports the belief that, with a few suitably located cathode-ray direction-finders, low-pressure areas could be traced as they approached Australia from the Indian Ocean and the Australian Bight, and in that way considerably earlier information obtained as to their existence than is possible by existing methods depending on barometric readings from land stations and one or two ships at sea.

4. Publications.

The following publications have been made during the past year as a result of the Board's investigations:—

Bulletin 59.—Radio Research Board: Report No. 2.

1. The State of Polarization of Sky Waves, by A. L. Green, M.Sc.
2. Height Measurements of the Heaviside Layer in the Early Morning, by A. L. Green, M.Sc.

Bulletin 60.—Radio Research Board: Report No. 3. .

1. The Influence of the Earth's Magnetic Field on the Polarization of Sky Waves, by W. G. Baker, B.E., D.Sc., and A. L. Green, M.Sc.

Bulletin 63.—Radio Research Board: Report No. 4.

1. A Preliminary Investigation of Fading in New South Wales, by A. L. Green, M.Sc., and W. G. Baker, B.E., D.Sc.
2. Studies of Fading in Victoria. A Preliminary Study of Fading on Medium Wavelengths at Short Distances, by R. O. Cherry, M.Sc., and D. F. Martyn, Ph.D., A.R.C.Sc.
3. Studies of Fading in Victoria: Observations on Distant Stations in which no Ground Wave is received, by R. O. Cherry, M.Sc.

At the present time, the following Bulletin is in the press:—

Bulletin No. 68.—Radio Research Board: Report No. 5.

Atmospherics in Australia: I. By G. H. Munro, M.Sc., A.M.I.E.E., and L. G. H. Huxley, M.A., D.Phil.

Several other reports are in preparation.

5. Acknowledgments.

Once again, acknowledgment is due to a number of organizations and individuals for the valuable co-operation they have furnished. The help of the Postmaster-General's Department and the Universities of Melbourne and Sydney has been continued on the previous lines. The Department of Defence has afforded valuable assistance in several ways, but notably by the loan of apparatus and the accommodation of equipment at Laverton (Victoria) and Liverpool (New South Wales). The Commonwealth Solar Observatory at Mt. Stromlo and the Watheroo Magnetic Observatory of the Carnegie Institution are also co-operating most helpfully in connexion with the work on atmospherics.

Buffalo Fly Investigations.

A Note on the Occurrence of *Hydrotaea australis* Malloch in Northern Australia.

By I. M. Mackerras, B.Sc., M.B., Ch. M., Division of Economic Entomology.

Muscid flies of the genus *Hydrotaea* are harmless as adults. Their larvae live in dung and are predatory on other Dipterous larvae. It is natural, therefore, that the use of these flies should be seriously considered in attempts to control such pests of stock as the stable fly, the horn fly, and the buffalo fly, all of which breed in cattle or buffalo dung. In 1928, and with this end in view, the Council obtained a consignment of *Hydrotaea dentipes* Fabr. from the Imperial Institute of Entomology. However, owing to inability to breed this species in captivity, permission to liberate was not requested, and the consignment was ultimately destroyed by Mr. G. F. Hill, who was in charge of the investigation.

Two Australian species of *Hydrotaea* have been described, *H. fuscocalyptrata* Macq. and *H. australis* Malloch.* Nothing was known of these beyond the original descriptions, and it was considered necessary that some knowledge of their habits, life-histories, and distribution should be obtained before undertaking further introductions of predatory flies. The present paper gives an outline of our present knowledge of *H. australis* Mall. More detailed accounts of the life history and biology of this insect will be published at a later date. *H. fuscocalyptrata* has not been recognized in recent collections.

Hydrotaea australis Mall. is a small, inconspicuous, dark-grey fly, which superficially rather closely resembles both *Fannia australis* Mall. and *Antipodomyia bancrofti* Mall., with both of which it has been confused in the past. The males are recognized by the presence of two strong spines near the apex of the fore femur, and the females by the presence of a pair of cruciate bristles in the middle of the frons. In addition, *F. australis* is slightly larger and darker, while *A. bancrofti* is more conspicuously marked with pale grey.

Adults are found commonly on horses and cattle, apparently feeding on the sweat and "scurf." On cattle, they have frequently been mistaken for buffalo flies. They were a source of considerable difficulty during a survey of the distribution of the buffalo fly in North Queensland, as it was necessary to throw the cattle or run them into a crush, in order to be certain of the identity of the flies. On the beast, they rest more horizontally than *Lyperosia*, their wings are not so iridescent and are held at a different angle, and the acute observer can usually detect the difference in the proboscis, which in *Hydrotaea* is of the normal Muscid form. They cause no obvious inconvenience to the host.

I have long been convinced that inspection of moving cattle is unreliable as a method of preventing the spread of the buffalo fly into clean country. It is difficult enough to detect buffalo flies, when present in small numbers, and the presence of *Hydrotaea* greatly increases the difficulties of the inspector.

The larvae and puparia are not unlike those of *Lyperosia*. They were first obtained in cattle dung at Wyndham, W.A., by Mr. T. G. Campbell, and have since been found in dung in many localities in northern Australia. They occupy the same stage of dung succession as the larvae of *Lyperosia*. The habit of devouring other larvae has not yet been actually observed in the laboratory, but Mr. H. Willings has reported that, when *Hydrotaea* larvae are present in a mass of dung, the larvae of *Lyperosia* are scarce. A detailed investigation of this point is being undertaken. Puparia of *Hydrotaea* are attacked by the local parasites, *Spalangia orientalis* Graham and *Phaenopria* sp., but apparently not so readily as those of *Lyperosia*. From the available information, it does not appear likely that these parasites exert any appreciable check on *Hydrotaea*.

Hydrotaea australis is widely distributed through the area at present occupied by the buffalo fly, namely, from Wyndham, in Western Australia to the Burketown-Normanton district in North-West Queensland. It also occurs in the area of potential spread of *Lyperosia*. I have bred it from dung at Springsure* and have seen a number of specimens collected and bred from dung by Dr. T. L. Bancroft at Eidsvold, South Queensland. Malloch also records it from Kendall on the North-Coast of New South Wales. In North Australia, it occurs throughout the year, both in the wet and dry seasons. There is insufficient information concerning its seasonal distribution further south, but it appears to be a warm weather species.

There is little doubt that *Hydrotaea australis* is a useful insect, and that it helps to reduce the numbers of adult *Lyperosia*. It is certainly of more use than any of the dung-eating beetles so far discovered, with the possible exception of a small species of Staphylinid, *Oxytelus* sp. Its actual economic value is, however, difficult to determine.

In view of the existence of a well adapted and widely distributed native species of *Hydrotaea*, it hardly seems reasonable to expect that the emergence of adult *Lyperosia* would be appreciably reduced by the introduction of another species of the same genus.

* Central Queensland.

NOTES.

The Brisbane Food Preservation Research Laboratory.

In a previous issue (Vol. 5, p. 133, 1932), a brief account was given of the programme of work proposed for the above laboratory, which was then in course of erection. The laboratory was formally handed over by the Queensland Meat Industry Board on the 26th July, 1932, and was accepted on behalf of the Commonwealth by the Minister in charge of the Council (Senator the Hon. A. J. McLachlan). The Board has generously provided, not only the necessary buildings, but also the full equipment and facilities, such as power, refrigeration, gas, &c.

The buildings so far erected consist of an office and two research laboratories, and three small refrigerated chambers. This unit, which is self-contained, has been built on the seventh floor of the main block of the abattoir, and is close to the main slaughter floor from which supplies of meat for experimental purposes will be drawn.

The insulated chambers have been designed especially for a study of the chilling of beef, with the view to discovering a method whereby Australian beef, as quarters, may be exported in the chilled state to Great Britain; the chambers, therefore, will be used initially almost exclusively for this purpose.

In order to maintain relatively constant temperature conditions, an insulated air lock has been provided into which the doors of the chambers open. The external walls are constructed of brick, and the partitions between each chamber of 3-in hardwood.

The insulation provided generally has been 5-in. slab cork on the ceilings, and 4-in. slab cork on the walls. As the ceiling of the sixth floor is well insulated, it has been deemed necessary to provide only 3 inches of cork on the floors of the two chambers in which it is desired to maintain strictly constant temperatures.

The cork insulation has been surfaced and rendered moisture-proof by means of $\frac{1}{2}$ -in. asphalt cement. An attractive appearance has been created by finishing the internal walls with several coats of cold-resistant white paint.

One chamber will be devoted entirely to the initial chilling of the hot sides of beef, and will therefore simulate conditions which will ultimately be practised in meat works exporting chilled beef. This side-chilling chamber is 7 ft. 6 in. x 11 ft. 6 in. x 11 feet average height, and, as rapid cooling of the beef is desired, it has its own refrigerating unit of the wet battery—air circulation type. The battery consists of 576 feet of 2-in. ammonia-expansion piping, over which sodium chloride brine is continually trickled. The chamber is cooled by drawing air through the battery and delivering it over a ceiling trunk-way, and returning it through trunk-ways placed at floor level; the fan used is the multi-vane centrifugal type. This chamber will accommodate fourteen sides of beef.

After the initial chilling of the beef to a temperature of 34° F. (approx.), the sides will be cut into quarters and then placed into either of two similar chambers having internal dimensions of 8 ft. 6 in. x 11 ft. 6 in. x 10 feet average height. Each chamber is cooled by the circulation of air over a dry brine-grid battery placed at the wall opposite to the door. Brine at either of two desired temperatures is supplied from refrigerated tanks placed in an adjacent small room. The method of air-circulation is similar to that employed in the side-chilling chamber. In these quarter-holding chambers, investigations will be made of the physical conditions and composition of the atmosphere which will have to be maintained in ships' holds carrying chilled beef from Australia to England, a voyage occupying about seven weeks. Accommodation is provided in each chamber for hanging fourteen quarters of beef.

The beef for experimental purposes will be brought on special trolleys from the slaughter floor, will be hoisted on to the meat rail, external to the air lock, and then run into the chambers, each being adequately provided with the necessary tracking and switches.

A unit for the study of the rapid freezing of meat is at present being erected in one of the Meat Industry Board's cold storage chambers. It will consist of a simple sodium chloride brine tank cooled by ammonia expansion pipes, and facilities for the immersion of the meat in the liquid freezing medium.

The two laboratories provided consist of a large general room for chemical and physical studies, and a small room for bacteriological work. The latter is also fitted as a dark room, wherein studies of the oxidation of fats may be carried out, since light is a potent catalyst in promoting such oxidation.

While most of the apparatus employed is similar to that in general use in chemistry and physics laboratories, for investigations on the chilling of beef, the need is apparent for extensive and accurate apparatus for the measurement of temperature, relative humidity, and rate of air flow. Of the extensive equipment of this nature, an interesting feature is the dual range, six-point chopper-bar, continuous temperature recorder. This instrument, which has an accuracy of $\pm 0.2^\circ \text{C.}$, will partially obviate the need for continuous personal observations of the temperatures of the air, brine, and meat during the lengthy period of six to eight weeks, when a storage experiment is being conducted.

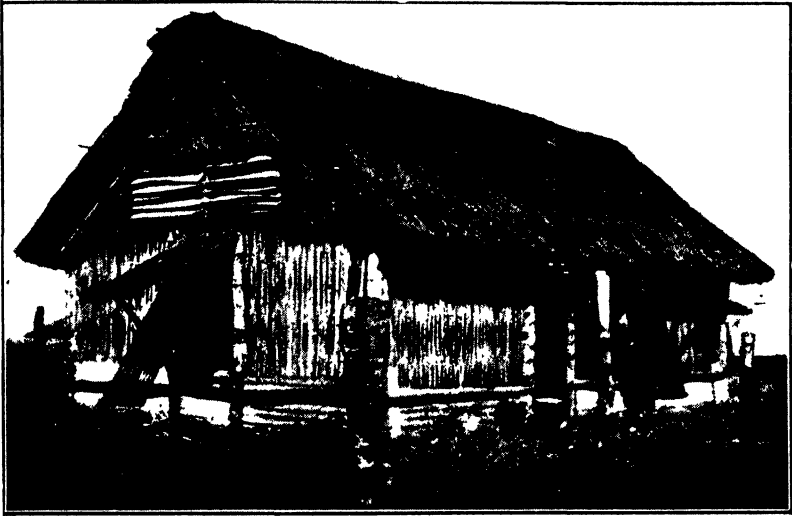
The Buffalo Fly Laboratory in North Australia.

The entomologist is not always surrounded by the amenities of life and modern science. Frequently he has to shift for himself and improvise the apparatus necessary for his work. This is especially true of the Council's buffalo-fly investigations in Northern Australia. How one great need, that of satisfactory laboratory accommodation, was met is illustrated in the photograph opposite.

The introduction of parasites from the Netherlands Indies was contemplated, and it was therefore necessary that the building should be suitable for studying these parasites under quarantine conditions.

Mr. H. Willings accordingly drew up a plan, and acted as his own foreman. The building was completed in five weeks, and, though a trifle hot in the wet season, has served well both as a quarantine insectary and as a home.

Land and facilities were made available at Burnside Station, North Australia, through the kindness of the Australian Investment Agency, and all materials except the wire gauze for the insectary cubicle were obtained locally. The total cost was under £50.



The Buffalo Fly Laboratory in North Australia.

The building consists of an outer shell 30 feet x 15 feet, built of ironwood, thatched with grass, and walled with split bamboo. The floor is made of ant-bed material. Inside, there is a central insectary cubicle 10 feet x 6 feet, walled with 60 mesh phosphor-bronze gauze. Between the insectary and one end, there is a small general laboratory fitted with bench, shelves, &c. The other end forms the living quarters of the research officer, and between the insectary and the back wall, there is good storage space for all reserve materials.

The laboratory has been used for detailed studies of the buffalo fly and other dung breeding insects, and especially for the breeding and study of the various races of the parasitic wasps, *Spalangia sundaica* and *Sp. orientalis*, which Professor Handschin introduced from the Netherlands Indies. Already, a considerable number of these wasps have been liberated locally, and Mr. T. G. Campbell is at present liberating the first consignment in North-west Queensland.

I.M.M.

Tests of the Holding Power of Nails.

(Contributed by I. Langlands, Division of Forest Products.)

In the study of the various types of wooden containers and of their relative efficiency in service, the Division of Forest Products has found that insufficient consideration is given to nailing. Although laboratory and service tests have repeatedly demonstrated that the strength of containers depends largely on the efficiency of the nailing, it is apparently not generally known that the nailing is the weak point in practically all commercial boxes and crates.

Nailed joints may fail by—(i) the nail heads pulling through the wood; (ii) the shearing of the wood from the nails; (iii) the nails breaking; or (iv) the pulling of the nails from the wood—the most common failure encountered.

The holding power of a nail depends on several factors, the most important of which are:—(a) the nature of the wood used; (b) the density of the wood used; and (c) the character of the nail itself. Tests have shown that the holding power of the wood increases with increase in density, and that, in general, the porous timbers (woods of the oak or ash type) have a greater holding power than the non-porous timbers (woods such as hemlock, spruce, or the pines). The characteristics of the nail which influence its holding power are the nature of the point and the character of the shank. In general, the sharper the point of the nail, the greater the holding power, provided splitting does not occur; but, on the other hand, the sharper the point, the greater the tendency of the wood to split, with consequent loss in holding power.

It is necessary to use a nail with a blunt point when working with woods which split easily in nailing. The extreme example of this type is the "dump" nail, which has no point at all. (The point of the common flat-headed nail has about the right degree of sharpness for most woods, being neither too sharp nor too blunt. If it were sharper, splitting would be likely to occur, whereas if it were blunter, its holding power would diminish.)

The second characteristic affecting the holding power of a nail is the nature of the shank. The ordinary wire nail depends for its holding power on the friction between the nail and the adjacent wood fibres. Attempts have been made throughout the world to improve the holding power by increasing the frictional resistance to withdrawal, or by substituting (at least in part) mechanical for frictional holding. The principal methods used overseas are (i) cement-coating; and (ii) barbing.

Cement-coated nails are made by tumbling ordinary nails in a drum with a resinous compound, which forms a thin coating on the nail, and increases its frictional resistance to withdrawal. This type of nail is largely used in England and America, and is probably the most popular variety having increased holding power.

As the name implies, the barbed nails have barbs cut into their shanks—the idea being that the barbs catch in the wood and resist withdrawal. However, extensive tests by the United States Forest

Products Laboratory have shown that the holding power of barbed nails driven into dry wood is less than that of plain nails, due to the fact that the barbs badly mutilate the wood fibres. On the other hand, the holding power of barbed nails driven into green timber, which has then been allowed to dry, is somewhat greater than that of plain nails treated similarly.

In Australia, several different types of special nails have been developed, all of which are claimed to have better holding power than the plain nail. The most common types are the twisted (or spiral) and the barbed (or jagged) nails. The shank of the former is twisted into a long spiral on the theory that the nail when driven will rotate like a screw, with resultant increase in holding power. The barbed nails made in Australia are rather different from those made overseas, being usually provided with notches or depressions rather than barbs, so that their behaviour is not necessarily the same as those tested by the United States Forest Products Laboratory. Cement-coated nails, although on the Australian market, have not come into favour. Other special nails produced in Australia are the chemically rusted nail and the sand-rumbled nail.

In its work in connexion with the testing of wooden containers, the Division of Forest Products was quickly confronted with the lack of knowledge on the relative merits of the various types of nails made in Australia. It was necessary, therefore, to obtain this information, and a comprehensive series of tests is being carried out to determine the relative merits of eighteen different types of local nail. The nails for these tests have been supplied by all the principal makers in the Commonwealth.

It has been decided to determine the holding power of the nails under the following conditions:—

- (i) Driven into dry wood and pulled immediately.
- (ii) Driven into dry wood and pulled three months after driving.
- (iii) Driven into green wood and pulled immediately.
- (iv) Driven into green wood and pulled after the wood has dried.

(In all tests, nails are driven into quarter and back faces, as well as end grain.)

Some nails, once they commence to yield, have very little holding power, and can be easily withdrawn. Others, even after they have started to move, still retain a firm grip on the wood, and considerable strain is necessary throughout the extent of their withdrawal. Obviously, these differences indicate important factors in the efficiency of the nails, and they also will be studied.

The results of all these tests when completed should prove of considerable interest to users of nails.

Electrical Moisture Meters for Timber.—Further Correction Figures.

The Division of Forest Products recently issued Trade Circular No. 9, describing electrical moisture meters. In these instruments, the moisture content of timber is determined by measuring indirectly the electrical resistance of the timber, but as the resistance varies somewhat from species to species at the same moisture content, small corrections are necessary when a moisture meter is used on a number of different timbers.

As an appendix to the trade circular, a table was given containing the corrections necessary for a number of common Australian and other timbers. Further tests on other species have added to this information, and the following table contains the additional correction figures. It is advised that this table should be inserted after Appendix I. in Trade Circular No. 9.

APPENDIX II. (TRADE CIRCULAR NO. 9).

Corrections Used with Blinker Sorters for Different Species of Timber.

For moisture contents in the neighbourhood of 12 to 15 per cent.

Species.				
Botanical Name.		Common Name.		
<i>Eucalyptus albens</i>	.. ..	White box	.. ..	0
<i>Eucalyptus bicolor</i>	.. ..	Black box	.. ..	0
<i>Eucalyptus bosistoana</i>	.. ..	Gippsland box	.. ..	-1
<i>Eucalyptus consideniana</i>	.. ..	White ash	.. ..	+1
<i>Eucalyptus goniocalyx</i>	.. ..	Mountain grey gum	.. ..	+2
<i>Eucalyptus hemiphloia</i>	.. ..	Grey box	.. ..	0
<i>Eucalyptus leucoxydon</i>	.. ..	S.A. blue gum	.. ..	0
<i>Eucalyptus maculosa</i>	.. ..	White gum	.. ..	-3
<i>Eucalyptus maideni</i>	.. ..	Spotted blue gum	.. ..	+2
<i>Eucalyptus melliodora</i>	.. ..	Yellow box	.. ..	+1
<i>Eucalyptus muelleriana</i>	.. ..	Yellow stringybark	.. ..	+3
<i>Eucalyptus viminalis</i>	.. ..	Manna gum	.. ..	0
<i>Tristania conferta</i>	.. ..	Brush box	.. ..	-4
<i>Podocarpus dacrydioides</i>	.. ..	N.Z. white pine	.. ..	0

Notes on the Casein-Formalin Treatment of Butter Boxes for the Prevention of Wood Taint.

(Contributed by W. J. Wiley, M.Sc.)

Experimental work on the casein-formalin treatment of butter boxes previously described in this *Journal* (Vol. 5, No. 1, 1932, pp. 5-24) has been proceeding, and the following notes are the outcome of experience gained in the treatment of a comparatively large number of experimental boxes.

The casein solution has been used at the same concentration as before. If a more concentrated solution is used, drying is, of course, quicker, but for satisfactory spraying, the solution must be warmed in order to decrease the viscosity. It has been found advantageous to increase the formalin concentration, and this is now made up by diluting 1.5 volumes of 40 per cent. formalin with 10 volumes of water.

The two solutions are sprayed on the box shooks simultaneously from a double-spray gun, the sprays mixing when they hit the surface of the timber. The reaction between the casein and formalin is rapid, and in a few seconds the coating sets to a jelly which does not sink into the wood, but dries, leaving a hard varnished surface. The double-spray gun is made from two guns fitted with special nozzles. These are necessary in order that (i) the two sprays, casein and formalin solutions, differing greatly in viscosity, may be of the same size to ensure thorough mixing over the whole treated surface; and (ii) that the correct proportions of the two solutions are delivered. When using these spray guns, the formalin solution is gravity-fed, and the casein solution fed by air pressure to the guns. A pressure of 20 lb. per square inch on the casein pressure pot, and 80 lb. on the pistols for atomizing, has been found suitable with casein solution of the usual viscosity. Approximately 1.5 lb. of casein solution and 0.2 lb. of formalin are delivered per minute. It has been found possible to kiln-dry the sprayed boards in half an hour, at a temperature of 140° F., and 20 per cent. humidity.

“Strathcona House”—A Hostel for Research Workers Visiting the Rowett Institute.

One of the features of the research work now being carried out in various parts of the Empire is the ever-increasing amount of co-ordination of effort, and its concomitant, the ready interchange of research information. It will be remembered that suggestions for the development of machinery whereby these actions might be facilitated were included in the recommendations of the 1927 Imperial Agricultural Research Conference.

That Conference considered that one of the means of rendering Empire research work effective was to arrange for exchanges of officers. The Rowett Research Institute, Aberdeen, has been very active in this way, and already one or two Australians, together with research workers from other Dominions, have been accommodated at the Institute, and have made themselves familiar with its well-known investigations in the field of animal nutrition.

A recent development at the Institute is the erection of “Strathcona House,” which is a residential club or hostel for research workers attached to the Institute, or who might be visiting it. Workers from the Dominions, or visitors from the Dominions, are given the first claim to bedroom accommodation. In the past, such people necessarily had to live in lodgings. Now, however, when they go to Aberdeen they will be met and taken to “Strathcona House,” introduced to all the other people staying there, and made members of the residential club.

It is believed by the Director of the Institute, Dr. Orr, and by others who have helped in this new move, that the educational value of the associations of “Strathcona House,” and of the contacts made there, will be quite considerable, and will be by no means an unimportant aspect of an investigator’s stay at the Rowett.

Note on an Improved Design for Electrical Resistance Thermometers for Measuring the Gradient of Temperature in Foodstuffs.

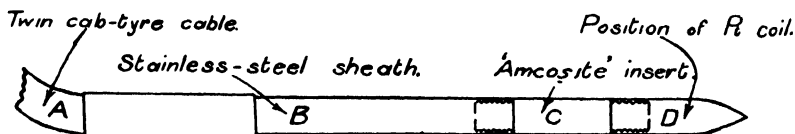
(Contributed by N. E. Holmes, B.E.E., and J. R. Vickery, Ph. D.)

In connexion with investigations into the preservation of foodstuffs by cold, it is often necessary to determine accurately the gradient of temperature in the actual foodstuff under treatment.

In the freezing of meat, for instance, the gradient may be of the order of 3°C . per inch, and, therefore, it is necessary to employ thermometers, giving, as nearly as possible, the temperature at a point. Moreover, the gradient of temperature must frequently be measured by distant reading instruments situated outside the chamber in which the foodstuff under observation is being cooled. Electrical resistance thermometers are usually convenient instruments for such long-distance measurements. In such thermometers, the requirements are:—

- (a) Rapid response to changes of temperature.
- (b) Restriction to a minimum of the volume whose average temperature is to be measured.

The drawing below shows the general details of an electrical resistance spear thermometer we have designed to incorporate the above requirements, to withstand corrosion by the foodstuff, and to be sufficiently robust to withstand the strains set up when the foodstuff freezes.



Several features of the instrument have already been developed by scientific instrument makers in England. Thus, to obtain the requirement (a) above, the platinum resistance coil D has been confined to the small dimensions of about 0.5 inch in length and 0.15 inch diameter, the coil being cased in a thin stainless steel sheath B.

To improve the thermometer with respect to requirement (b) above, the "Amcosite"* insert C has been introduced. Since the thermal conductivity of steel is approximately 250 times that of "Amcosite," the use of this insert will reduce considerably the conduction of heat along the casing of the thermometer. The importance of this feature will be realized when it is stated that the difference of temperature along the stem of a thermometer thrust to the centre of a piece of meat 10 inches in thickness may be 20° to 25°C .

* "Amcosite" is a composition having characteristics similar to ebonite.

Apple Cases for the Export Trade.—Investigations Designed to Develop the Best Type.

In an article written shortly after his return from a visit to Great Britain, Mr. W. M. Carne, Senior Plant Pathologist of the Division of Plant Industry, drew attention to the little that is known about the different methods of packing Australian fruit in relation to the condition of the fruit so packed when eventually it landed on overseas' markets (see this *Journal* 5: 40, 1932).

He also drew attention to the serious damage caused to Australian apples by bruising during transport abroad.

With a view to remedying this position some investigations have been initiated by the Council's Divisions of Plant Industry and Forest Products working in co-operation, the actual experiments being conducted at the headquarters of the Division of Forest Products in Melbourne, where the necessary facilities are available. The work, which is naturally of a seasonable nature, is being undertaken by Mr. Carne and by Mr. R. F. Turnbull, the latter an officer of the Division of Forest Products.

Attention is being given in the first instance to the two types of case in general use in the apple export trade, namely the Australian bushel (dump) case and the standard bushel case. These are being packed in different ways and with different weights of fruit. The cases are then subjected to dropping and bumping tests with the special equipment which the Division of Forest Products has for that work and the degree of bruising is noted.

By such methods it is hoped, in the first instance, to give a definite answer as to the best procedure to adopt in packing the individual boxes of apples intended for transport overseas and eventually as to how present methods, including, perhaps, box design, could be improved and standardised. In the latter connexion the Standards Association of Australia is taking considerable interest in the work, and with that end in view has set up a special committee on fruit cases.

Some preliminary work was carried out early in 1932, but its object was chiefly the development of a suitable technique for the more extensive investigations it is hoped to continue in the next apple season (early in 1933). Apart from the information regarding the best technique of testing, one or two interesting indications were obtained from the 1932 work, particularly in regard to the relative tightness of pack and its effect on bruising. It was found, for instance, that there is a definite relation between tightness of pack and the amount of bruising; further, that it is easy to pack over-tightly, and by so doing to increase the amount of damage.

The Investigation of "Peg-Leg Disease" of Cattle.—Co-operation of Queensland Producers.

In a previous note (see Vol. 5, page 131) it was mentioned that, as part of the cattle investigations being carried out in co-operation with the Queensland Department of Agriculture and Stock and the Empire Marketing Board, it was proposed to study the so-called peg-leg disease

which affects cattle in certain parts of Queensland. There are indications that the trouble is caused by some deficiency, possibly phosphorus, but further studies of the condition are needed before the cause can be stated with certainty and thus the most economic means of control developed.

It was realized that it would be of considerable value from the investigational point of view if arrangements could be made to carry out some work at a small field station. As a result of active co-operation which has recently been given by certain cattle interests in Queensland, it will be possible to make much faster progress along such lines than would otherwise have been the case. The co-operation in question is outlined below.

Mr. Archie Black, of "Helenslee," near Charters Towers, has granted the use of some of his paddocks, yards, &c., besides undertaking the general management of the experimental stock, all of which has been rendered available by pastoralists of the district. In addition, through the Graziers' Association of Central and North Queensland, a number of local cattle producers and several meat exporting companies have contributed upwards of £135 towards the cost of the field station operations. Such assistance is not only appreciated from the financial point of view, but the practical evidence of keen interest in the work is a source of particular gratification.

Recent Publications of the Council.

Since the last issue of this *Journal*, the following Bulletins and Pamphlets of the Council have been, or are just about to be, published:—

Bulletin No. 65.—"Downy Mildew (Blue Mould) of Tobacco in Australia," by H. R. Angell, B.Agr.Sc., Ph.D., and A. V. Hill, B.Agr.Sc.

The results of work carried out by the Division of Plant Industry on behalf of the Australian Tobacco Investigation are recorded. The purpose of the investigations was to find out essential facts regarding the life history of the blue mould parasite and its relation to the host plant, such information to serve as a guide to further work in methods aiming at the control of the disease, which is a serious problem to the Australian tobacco industry. The causal organism is a species of *Peronospora*. It is carried over in over-wintering plants, including cultivated ornamental species of *Nicotiana*. There is some evidence, too, that it is transmissible through infected seed. As the organism appears to be strictly parasitic, there seems to be little danger of disease due to its possible persistence in the soil.

Bulletin No. 66.—"The Influence of Growth Stage and Frequency of Cutting on the Yield and Composition of a Perennial Grass—*Phalaris tuberosa*," by A. E. V. Richardson, M.A., D.Sc., H. C. Trumble, M.Agr.Sc., and R. E. Shapter, A.A.C.I.

This is one of the reports of investigations in the field of mineral deficiencies of pastures, being carried out as the result of contributions by the Empire Marketing Board, the Waite Agricultural Research Institute, and the Council. In the work reported, the crude protein

content of the herbage fell from 33 per cent. at the early tillering stage, to 3.37 per cent. at maturity; the percentage of crude fibre and nitrogen-free extractives increased continuously from tillering to maturity; the phosphate and potash content of the dried herbage was exceedingly high in the early stages of growth, and fell steadily to a minimum value at the mature stage; when only 10.6 per cent. of the total dry matter in the herbage had been accumulated, and only 5.1 per cent. of the total water used had been transpired, the plant had nevertheless assimilated 66.2 per cent. of its total nitrogen; and a substantial and absolute loss of potash occurred from all portions of the plant during the final stage of growth, which must be regarded as a migration of potash from the plant to the soil, due possibly to diffusion from the root system at the stage when physiological activity ceases. The yield of herbage, butts, and roots, was considerably reduced by increasing the number of cuts, e.g., cutting five times reduced the yield of herbage by 54 per cent., and the root system by 78 per cent. Notwithstanding the fact that the yield of herbage was decreased considerably, with an increased number of cuts, the actual yield of protein was greatly increased; the yield of nutrients per litre of water transpired is greatly increased by increased severity of cutting.

Bulletin No. 67.—"Methods for the Identification of the Coloured Woods of the Genus *Eucalyptus*" (Division of Forest Products—Technical Paper No. 5), by H. E. Dadswell, M.Sc., and Maisie Burnell, B.Sc.

The practical importance of establishing methods of identification of Australian eucalypt timbers is constantly being brought to the notice of the Division of Forest Products. Bulletin No. 67 gives the results of work done to date, with such a development in mind. A first division has been made on the basis of colour, and the publication is confined to the coloured eucalypts (as distinct from the non-coloured). These have been studied macroscopically, microscopically, and, in some cases, chemically. A feature of the work was the care given to the selection of samples, and no studies were made on any sample unless its correct botanical classification was certain, after an examination of the botanical material from the tree from which the log was cut. The bulletin contains a number of illustrations of typical photomicrographs of the eucalypts discussed.

Bulletin No. 68.—"Radio Research Board: Report No. 5. Atmospherics in Australia—I.," by G. H. Munro, M.Sc., A.M.I.E.E., and L. G. H. Huxley, M.A., D.Phil.

The paper describes the progress of an investigation of the atmospherics which interfere with radio reception in Australia. This has been carried out by means of cathode-ray direction-finders, one located at Laverton, near Melbourne (Vic.), and the other at Mt. Stromlo, near Canberra (F.C.T.). Information is accumulating from which it will be possible to predict the interference to be expected from atmospherics on any wave-length at any place in Australia—a matter of considerable importance to radio services, particularly those concerned with broadcasting. In addition, the observations definitely indicate that atmospherics are due to lightning strokes. Further, as the instruments can easily detect the source of atmospherics 2,000 miles or more

away, their value in giving earlier information of approaching bad weather than possible with existing barometric methods of forecasting is obvious. They would be of particular value to aircraft services to give information regarding the position of local storms.

Bulletin No. 69.—"An Investigation of the Taxonomic and Agricultural Characters of the *Danthonia* Group," by A. B. Cashmore, B.Sc.

This is another publication concerning the mineral deficiency investigations mentioned in Bulletin No. 66 above. The literature on the value of the *Danthonia* species (wallaby grasses) for grassland work is brought together and discussed. It is stated that the species are low fertility demanders, and that they are able to adjust themselves to extremes of rainfall and temperature conditions. When mature, the feed tends to be coarse and fibrous, and somewhat unpalatable to stock, but if maintained at an immature stage of growth by rotational grazing, good yields of highly nutritious fodder may be expected at low water cost. The work carried out shows the possibility of obtaining further strains for use in the drier areas of Australia where introduced species of pasture plants are unable to persist. The extended production period of *Danthonia* and its capacity to produce green feed after rain in hot summers are stressed. These qualities are of particular value where wool production is the aim.

Bulletin No. 70.—"A Soil Survey of King Island," by C. G. Stephens, M.Sc., and J. S. Hosking, B.Sc.

The soil survey of King Island, which is reported in this Bulletin, was undertaken at the request of the Tasmanian Department of Agriculture, in order to provide a basis for the advisory and experimental work of its veterinary and agricultural officers. The stock problems of King Island have acquired something more than mere local interest, owing to the development of "coastiness," a disease of stock, akin to the "bush sickness" of New Zealand, which is quite definitely associated with the calcareous sandhills of the west coast, and which, like other cases of "coastiness" in Australia, can be cured by transferring the stock to other areas. Eight soil types have been identified and named. The coastal disease is particularly associated with the type to which name "Currie calcareous sand" has been given.

Pamphlet No. 31.—"A Preliminary Report on Investigations on the Buffalo Fly (*Lyperosia exigua* de Meij) and Its Parasites in Java and Northern Australia," by Professor E. Handschin.

The pamphlet consists of a preliminary report, recording the results of two years' investigations by Professor Handschin, of the University of Basle, who was brought out by the Council for the purpose. The report gives a number of details concerning the life history of the buffalo fly, and of its reactions to different stimuli and environments. An account is also given of experiments in cross breeding an Australian variety of *Spalangia* (*S. orientalis*) with a Javan variety (*S. sundaica*), both of which varieties parasitize the puparia of the buffalo flies, and thus eventually destroy them. In addition, the various habits of these species of *Spalangia* have been studied. It has been found, for instance, that females are attracted to dung still moist and containing

buffalo-fly puparia, while males are attracted to dry dung in which females are emerging. This last ensures the meeting of the sexes at the time that buffalo-fly puparia are forming in the dung. Genetical experiments with the Australian-Javan cross of *Spalangia* show that females of the Australian variety, crossed with males of the Javan variety, live twice as long as normally, and lay three times as many eggs. The reverse cross is ineffective. At the present time, an effective cross that has been bred up is being liberated in North Australia with a view to observing its effect.

Pamphlet No. 32.—"The Chemistry of Australian Timbers, Part 2—The Chemical Composition of the Woods of the Ironbark Group" (Division of Forests Products—Technical Paper No. 4), by W. E. Cohen, B.Sc., A. L. Baldock, B.Sc., and A. G. Charles.

There is a general trend in forest products research towards utilizing wood substances after some form of chemical transformation. Other investigations involve altering the physical characteristics of wood, to increase its resistance to fire, and to reduce in seasoned timber the absorption of and loss of moisture, with consequent swelling and shrinkage. Such proposals, and those associated with converting wood into paper, artificial silk, lacquers, &c., must have their foundation in a fuller knowledge of the chemistry of timber. For this reason, *inter alia*, the Division of Forests Products is carrying out some work in the chemical field. The work reported in the pamphlet shows that the Ironbark eucalypts differ in chemical composition from the hardwoods of North America, and that an outstanding feature in the Australian timbers is the presence of large quantities of gum-like substances, which are found in the various wood cells, and which are insoluble in the organic and neutral solvents usually employed in wood analysis. Numerous regular differences in certain chemical factors such as alkalinity of ash, cellulose content, and percentages of "solubles" in various solvents, were found, and the possibility of employing these as an aid to timber identification is indicated. Another result of the work is valuable information regarding the degree of fineness to which it is necessary to grind timber samples, in order that resultant analyses may be a correct reflex of the composition of the original timber.

Pamphlet No. 33.—"Enzootic Haematuria (Haematuria Vesicalis) of Cattle in South Australia," by L. B. Bull, D.V.Sc., C. G. Dickinson, B.V.Sc., and A. T. Dann, M.Sc.

Haematuria vesicalis or "redwater" of cattle is described as it occurs in a certain restricted area of South Australia. Attention has been given to the geological nature of the country, to urine analyses, to the soils, and to the pastures. Urine analyses have so far failed to reveal the presence of an irritant, which might be calculated to cause the lesions in the bladder. Certain differences in the proportion of the urinary constituents, from those found in normal cows' urine, have been demonstrated, but no etiological significance can be attached to these findings at the present time. No attempt is made to discuss the distribution of the disease throughout the Commonwealth, but attention is drawn to its occurrence elsewhere, notably in Victoria and Tasmania, as well as to its former appearance in New Zealand. There is also evidence that it occurs in at least one restricted area in southern Queensland.

Pamphlet No. 34.—"The Collembola-Symphyleona of Australia: A Preliminary Account," by H. Womersley, A.L.S., F.E.S.

The pamphlet contains a report, dealing with the systematics of the group of insects containing the lucerne flea (globular springtail) which is causing such damage to pastures in various parts of Australia. It contains a foreword by Dr. R. J. Tillyard, M.A., F.R.S., in which the economic value of the work is discussed, and in which it is pointed out that a study of the systematics of the group is an essential preliminary to any comprehensive investigation of the possible control of the individual members of the group. It is also mentioned that a predatory mite of the genus *Biscirus* is an effective biological agency controlling the lucerne flea in a few restricted areas of Western Australia.

Pamphlet No. 35.—"Pulpy Kidney' in Lambs." (1) "'Pulpy Kidney,' or Acute Infectious Entero-toxaemia of Sucking Lambs due to *B. ovitoxicus* (Bennetts)," by D. T. Ozer, B.V.Sc. (2) "'Pulpy Kidney'—A Post-mortem Change in Experimental Infectious Entero-toxaemia," by H. W. Bennetts, D.V.Sc.

This publication consists of two reports of work carried out as a part of the Australian Pastoral Research Trust-Empire Marketing Board scheme, and in co-operation with the Departments of Agriculture of Tasmania and Western Australia. It has resulted in the important demonstration that "pulpy kidney" of lambs, which often causes serious losses to producers of fat lambs in Tasmania and the Eastern States, is due to the same organism, namely, *Bacillus ovitoxicus*, that causes the so-called braxy-like disease of sheep in Western Australia. The development of an economic method of control is thus correspondingly nearer.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 71.—"Investigations on Irrigated Pastures." 1. "The Yield and Botanical Composition of an Irrigated Permanent Pasture under Various Systems of Pasture Management," by A. E. V. Richardson, M.A., D.Sc., 2. "The Chemical Composition of Irrigated Pastures at Wood's Point, South Australia," by H. P. C. Gallus, B.Sc.

Bulletin No. (?)—"A Soil Survey of the Nyah, Tresco, Tresco West, Kangaroo Lake (Vic.), and Goodnight (N.S.W.) Settlements," by J. K. Taylor, B.A., M.Sc., F. Penman, M.Sc., T. J. Marshall, B.Sc. (Agr.), and G. W. Leeper, M.Sc.

Pamphlet No. 36.—"Fibre Boards—Their Use, and the Possibilities of Their Manufacture in Australia," by R. F. Turnbull, B.E.

Pamphlet No. (?)—"The Blowfly Problem in Australia, edited by R. J. Tillyard, D.Sc., F.R.S., and H. R. Seddon, D.V.Sc.

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COMMONWEALTH



OF AUSTRALIA

JOURNAL

OF

THE COUNCIL FOR SCIENTIFIC

AND

INDUSTRIAL RESEARCH

VOLUME 6

1933

17095/'36

Editor: G. A. COOK, M.Sc., B.M.E.

Annual Subscription, 5s. Post Free

(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 6.

FEBRUARY, 1933.

No. 1.

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Journal of the Council for Scientific and Industrial Research.

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FEBRUARY, 1933.

No. 1.

The Work of the Council for Scientific and Industrial Research.

The article that follows consists of a radio address which was broadcast on the 14th December, 1932, by Senator the Hon. A. J. McLachlan, Vice-President of the Executive Council and Minister in charge of the Council for Scientific and Industrial Research. The address was broadcast simultaneously from stations 3LO Melbourne, 2CO Corowa, 2FC Sydney, and 2NC Newcastle.—Ed.

By courtesy of the Australian Broadcasting Commission, I am greatly privileged to be able to address you on the subject of scientific research.

Before I tell you something about the work of the Council for Scientific and Industrial Research, and the valuable results it has already achieved, I will just indicate very briefly the reasons why the Commonwealth Government considers that it is very important in the national interest to support this sphere of activity.

It is a truism that the prosperity of mankind depends very largely on the advancement of knowledge. Since the industrial revolution, we have seen a whole succession of fundamental discoveries in science, resulting in the establishment of innumerable new industries, in revolutionary changes in the habits of man, and in the development of a completely new social order. During the past 150 years, the progress made in our command over nature, and in the improvement of the conditions of mankind in civilized countries, has been immeasurably greater than in all preceding years.

The fact that science is recognized as the foundation of the whole fabric of modern society need hardly be elaborated. One or two outstanding examples will suffice to illustrate that point.

The discoveries of Faraday were all made in the laboratory, and were believed originally to be of no practical importance, yet in his discoveries lay the germ of all the dynamos and the great systems

of electric power transmission of the present day, including the electric railways and tramways, without which modern transport would be impossible. The researches of Pasteur were commenced entirely from the point of view of pure science, and it was only later that he took up the application of his results first to fermentation problems and then to the control of disease. The discovery of electric waves which now broadcast information and entertainment over the earth arose from a mathematical investigation by Clerk Maxwell, and it took 20 years to bring these waves out of the realm of mathematical formulae into the realization of fact. The discoveries in heredity and cross-breeding, which were made initially by Mendel, and which have added millions to Australia's wealth, originally had no industrial objective in view. All these, and innumerable other fundamental discoveries, have reacted in an extraordinarily favorable way on the well-being and comfort of mankind.

One of the striking developments of recent years has been the recognition by Governments of the part played by scientific research as one of the most important factors of national welfare. In many countries, national scientific research institutions have accordingly been established for research in applied science in connexion with the more important industries of the particular countries concerned. In Australia, it is only too evident that an extraordinary number of important national problems exist. The rapid spread of imported pests, such as the prickly pear, the blowfly, and the buffalo-fly, when removed from their natural habitat, and from the factors that there kept them in control, is amazing. The breeding of plants of economic value capable of being grown in the drier parts of the continent; the development of methods whereby greater quantities of Australian-grown perishable foods can be placed on the markets of the world; means whereby our great timber resources can be utilized to best advantage; the examination and classification of our soils so that they may be profitably cultivated; the investigation of scientific problems affecting our great irrigation settlements; the control and eradication of animal diseases and other problems so vitally affecting our great pastoral industries, constitute other groups of problems which exist not only in one State of the Commonwealth but in every State.

Much work in regard to many of these problems has been carried out, and in this connexion a tribute is due to the magnificent efforts which have been made by State Departments of Agriculture, of Mines, of Forests, &c., and by the various Australian Universities. Nevertheless, it is quite clear that if our splendid opportunities are to be fully realized, Australian effort in the field of scientific research must be intensified.

In 1926, the Government accordingly decided to place the Council for Scientific and Industrial Research on a proper and effective footing, and it is pleasing to be able to record that that action, as well as the continued support of the Council, has received the general commendation of every party in the Federal Parliament, as well as approval and co-operation from very many outside organizations.

Our scientific research costs, from Government sources, between £60,000 and £70,000 per annum. This figure is most insignificant as compared with the expenditure of other countries. In England, for

example, in 1931, the sum of £87,000 was provided for the Fuel Research Board alone; £105,000 for the National Physical Laboratory; £38,000 for the Building Research Board; £68,000 for fisheries research; and £464,000 for agricultural research.

The figures for the United States of America are even more striking. In that country the Federal Department of Agriculture expends about £6,000,000 per annum on research, to which must be added very considerable expenditure on the part of the various States; the Bureau of Standards costs about £880,000; and the total funds voted to research by various American industries has reached the astounding figure of £40,000,000 per annum.

In Canada, the sum of £600,000 was expended recently on the construction of governmental research laboratories alone. Many other striking figures could be quoted in relation to other countries, like Japan, Germany, and so on, but for present purposes, the few illustrations which I have quoted serve to show the importance with which the world views scientific investigation.

To all those who are engaged in waging a gallant struggle against economic adversity, like the primary producer, I would especially stress the importance of science. At Ottawa, we obtained preferences for Australian products, but these advantages will be nullified, unless the quality of our products can be maintained at a standard competitive with that of other countries. This can be achieved only by the adoption of scientific processes.

The possible scope of the Council's investigations is very wide indeed, and having regard particularly to the amount of money and the supply of trained investigators available, the Council had soon after its creation to decide on the branches of work on which its efforts should primarily be concentrated. The principal work has accordingly been organized in the following groups or sections:—(i) plant industry; (ii) economic entomology; (iii) animal health; (iv) animal nutrition; (v) soils and irrigation; (vi) forest products; and (vii) preservation and transport of foodstuffs.

A great deal of the Council's work is carried out in close co-operation with other organizations, such as the State Departments of Agriculture, Universities, the Waite Agricultural Research Institute, and so on. The Council has, in fact, succeeded in bringing about a full measure of real co-operation among the bodies concerned with scientific industrial research throughout Australia. This has been achieved largely through the State Committees, which have been established in each State, and through the Standing Committee on Agriculture, which comprises amongst its members the permanent head of each State Department of Agriculture.

Nevertheless, it was obviously necessary for the Council to have certain research laboratories of its own. Laboratories for plant research and entomological investigations have been established at Canberra. At Adelaide, there are the Animal Nutrition and the Soils Laboratories—the former located in the grounds of the University of Adelaide, and the latter housed in a building made available by the generosity of the Darling family. At Sydney, there is the McMaster Animal Health

Laboratory, erected and equipped from the munificent gift of Mr. F. D. McMaster. At Melbourne, there is the Forest Products Laboratory. At Brisbane, there is the Cold Storage and Food Preservation Laboratory—the gift of the Queensland Meat Industry Board. Near Townsville, there is a laboratory for the investigation of animal health problems affecting cattle in North Australia. Then at Merbein, in Victoria, there is a research station for the investigation of problems affecting our dried vine fruits, and at Griffith, New South Wales, another research station for work on problems connected with the citricultural industry.

At its Plant Industry Laboratory, at Canberra, the Council is giving special attention to plant diseases, which cause an annual loss in Australia of £12,000,000 sterling. Already, results of very substantial value have been obtained. For example, the investigation on bunchy-top in bananas, a disease which was devastating our banana plantations, gave results which have been applied so successfully by the New South Wales and Queensland Departments of Agriculture that the banana industry has now been re-established on large areas in those States. Bitter pit in apples, which was so serious a menace to our export apple industry, has been shown to be intimately related to immaturity at picking time, and the annual loss of £100,000 in export apples may now be reduced to negligible proportions. Blue mould in tobacco, which often completely destroys tobacco crops in many parts of Australia, is being investigated, and already results having an important bearing on the control of the disease have been obtained. A commercial method of getting rid of water blister of pineapples, which causes a loss of £12,500 per annum, has been discovered. Spotted wilt in tomatoes, flag smut and root rots in wheat, and other diseases are being attacked, and good progress is being made.

At the Entomological Laboratories, one section is concentrating on the control and eradication of weed pests by introducing from abroad insects which destroy them. Insects which attack St. John's wort have been discovered, introduced, and acclimatized, and many thousands of them have been distributed in New South Wales and Victoria. Insects which attack Noogoora burr have been found in America, and already one species has been introduced into Australia. Consignments of a moth which destroys ragwort have been obtained from New Zealand, and have been liberated experimentally. As regards insect pests, a group of entomologists has been concentrating on the buffalo-fly pest, which is so serious a menace to Australia's cattle herds, and parasitic insects have been brought from the Dutch East Indies. The sheep blowfly pest is also being tackled vigorously, and already good progress has been made, particularly in the acquisition of a large amount of fundamental knowledge regarding the various species primarily responsible for attacking sheep.

Another important group of national problems which is being tackled by the Council is that relating to diseases of stock, particularly sheep and cattle. Perhaps the outstanding achievement in these investigations is the discovery and practical application of a vaccine against black disease of sheep, which is estimated to cause an annual loss of £1,000,000. The cause of the Beverley disease of sheep in Western Australia has been discovered, and a vaccine which has been evolved has given very satisfactory results. Successful results have also been obtained from the parasitological investigations which are now centred

at the F. D. McMaster Laboratory, in Sydney. At the Animal Health Research Station recently opened near Townsville, a number of important problems affecting cattle in Northern Australia are being investigated.

At its Animal Nutrition Laboratory, at Adelaide, the Council is concentrating its work almost entirely on a fundamental study of sheep with a view to building up a body of knowledge which will enable definite guidance and advice to be given to pastoralists so as to enable them to overcome certain serious difficulties with which they are faced. As a result of field trials in Queensland, it has been shown that under certain conditions it is possible to obtain an increase of over 30 per cent. in the weight of the fleece, at a relatively small cost. In certain parts of Australia the pastures are deficient in various mineral constituents which are essential to the well-being and growth of sheep, and investigations are being carried out in order to determine how these difficulties can best be overcome. Another important section of the nutrition work is that relating to the feeding of sheep in times of drought. The object of these investigations is to obtain full information regarding the amount of energy contained in various foodstuffs, their digestibility, and price. In this way the most economical methods of hand-feeding during periods of drought will be determined.

Investigations on soil problems have been concentrated mainly on the irrigation settlements, with the objects, firstly, of advising settlers as to the methods to be adopted in order to make their areas more productive, and secondly, to make investigations of the soils of virgin areas for future settlement. The survey work in the Murray River settlements will be completed in about two years' time, and the results obtained show not only that much of the loss on these settlements could have been avoided had the necessary investigations been made, but also that future developments in irrigation settlement can be undertaken with a full knowledge, so far as suitability of soils is concerned, of the conditions essential for successful production.

The dried fruits industry of Australia has an annual turnover of over £3,000,000, and the viticultural and citricultural industries have led to the establishment of thousands of homes in the irrigation areas, and to the expenditure of large sums of money on dams, channels, pumping stations, &c. Since the establishment of the Council's Research Station at Merbein, the yield of dried fruit per acre has been more than doubled, and this increase has been accompanied by a substantial improvement in quality. It may, in fact, be claimed that the present satisfactory condition of the industry is in no small degree due to the results of the Council's work, which results are each year becoming more and more generally applied, with consequent improvements in yields, processing methods, and quality, and enhanced prices for the products. An outside estimate has assessed the added value of the dried fruit crop at £8 per ton as the result of the work of the Merbein Research Station. Similarly, the work at the Citricultural Research Station, Griffith, is yielding most valuable results. The experiments have shown that citrus fruit yields can be profitably increased by the adoption of certain cultural and manurial methods, and these methods are now becoming the standard practice on the Murrumbidgee Irrigation Area, with a consequent increase in productivity, and reduction in cost.

The recently formed Division of the Council dealing with forest products problems, with its laboratory at Melbourne, has already achieved very great success. It has been instrumental in bringing about improvements of material value in many directions. As an example, the work on the use of Australian timbers for the manufacture of butter boxes may be mentioned. Frequent complaints have been received in the past that butter exported in boxes of Australian wood developed wood taint. Most Australian butter is at present exported in boxes of New Zealand white pine. The experiments have been most successful, and a rapid and cheap method has been developed for treating timber so as to prevent taint. The method is now being tested by semi-large scale shipments of butter to England. It is probable that the investigations will lead to the utilization of very large quantities of Australian timber in place of that at present imported.

Another important development is the establishment of an industry in Western Australia for the production of tannin extracts from waste karri and marri barks. This industry is based directly on the results of the research work of the Council, and is a gratifying conclusion to years of experiment. It is anticipated that the industry will develop an extensive export trade. A third development of great importance appears to have resulted in a definite promise of the establishment of the paper-making industry in Australia. In spite of the Council's successful work on the manufacture of paper-pulp from Australian timbers, it has for long been impossible to get any acceptance of the fact that our hardwoods can be used for the manufacture of paper. Difficulties are now being overcome, and the way is clear for the establishment of what may develop into one of our most important industries. Very satisfactory work, of much value to our timber industries, has also been done in the seasoning and preservation of Australian timbers, and in their utilization for many industrial purposes.

Until recently, the Council's investigations into problems connected with the preservation and transport of foodstuffs, particularly by cold storage, has been confined largely to isolated problems which, though yielding valuable results, were difficult to co-ordinate, and did not adequately cover the field of urgent investigations required. Though it had long been the intention of the Council to develop this field of investigation in view of its great importance, particularly to our export industries, lack of funds and of trained scientific investigators prevented the formation of a suitable organization. However, recently the Council has been able to establish a small section to deal in a more systematic way with these problems. At the laboratory at Brisbane, the problem of the export of chilled beef is being intensively investigated. The importance of this work lies in the fact that, owing to the longer voyage to England, Australian beef has to be frozen, and does not fetch so high a price on the London market as Argentine chilled beef. An investigation is also being conducted on problems connected with the export of pig carcasses to England for the manufacture of bacon. Work on the ripening and storage of bananas has been very successful, and the results are being adopted commercially. In Melbourne, work is in progress on the storage and transport of oranges, apples, and other non-tropical fruit.

Perhaps the most spectacular success achieved is in the destruction of prickly pear. This work was undertaken at the instance of the old Advisory Council of Science and Industry, and is being carried out

by the Commonwealth Prickly Pear Board. It is well known that already heavy growth of pear has been destroyed on millions of acres, and whilst there are certain aspects of the problem, such as the destruction of re-growth from the butts and roots of the old plants, the attack of parasites of *Cactoblastis* insects, and the destruction of the dreaded tiger pear, which still require close attention, there is reason to believe that in the course of a few years Australia will have succeeded in ridding itself of this great invasion, which constitutes the worst plant pest the world has ever known. Already areas previously covered by pear are being brought back into cultivation, and when it is realized that the prickly pear belt extends to no less than 60,000,000 acres, the enormous value of this extraordinarily successful work will be realized.

It is impossible to express in pounds sterling the value of the results already achieved, but it is very clear that it is many times greater than the total cost of the investigations. In fact, no type of effort is capable of returning higher dividends than scientific industrial research, particularly when applied to our primary industries. One of the most gratifying features of the Council's work is the evidence of appreciation it has received in the way of substantial grants, both in money and kind, from many commercial and industrial interests.

The Present Position and Future Prospects in Relation to the Biological Control of Prickly Pear.

By Alan. P. Dodd.*

The report that follows has been prepared by the Officer-in-Charge of the Commonwealth Prickly Pear Board's investigations, and has been made available by that body for publication. The Board is financed by contributions from the Council for Scientific and Industrial Research and the States of Queensland and New South Wales in the proportion of 2:1:1. At present, it is constituted as follows:—W. L. Payne (Queensland Department of Lands), (Chairman); G. Lightfoot (Council for Scientific and Industrial Research); Professor E. J. Goddard (Council for Scientific and Industrial Research); and G. D. Ross (New South Wales Department of Agriculture).

The work described in the report has been particularly successful, and quite an outstanding instance of the economic value of scientific research. This will be obvious when it has been seen from the report that the original pear infestation of 60 million acres—an area slightly larger than the whole State of Victoria, and also very little less than the total area of Great Britain and Northern Ireland—has all been attacked, and that with care there is every prospect of entirely ridding Australia of the pest in a comparatively short time. Science can thus fairly claim to have almost redeemed to Australia, and at a comparatively infinitesimal cost, a province of the size of the State of Victoria, and one which bade fair to become utterly useless.—Ed.

Summary.

The past three years have brought a very great change in the prickly-pear situation. Widespread destruction of the pest has followed the general establishment of *Cactoblastis*, to such an extent that the greater part of the original pear has collapsed in Queensland and the northern areas of New South Wales. In Queensland a vigorous policy of the development of pear lands for closer settlement is being pursued—a wonderful tribute to the efficiency of insect destruction.

But there is still particular need for scientific research and investigation. Re-growth, which invariably springs up after the initial collapse of prickly-pear, is a feature of the situation in many districts. Although *Cactoblastis* destroys this secondary wave of the pest readily, the Board is making a special endeavour to establish other insects for its more rapid control. Natural parasites kill a percentage of the *Cactoblastis* population; mortality from these agencies is not a serious factor and does not appear to be increasing; nevertheless, the question demands continued study. In the Hunter River districts of New South Wales, insect destruction has been much slower than elsewhere, but is now giving promise of eventual success.

The tiger-pear, *Opuntia aurantiaca*, which spreads very rapidly, is being made the subject of a special investigation for the introduction of its particular insect enemies. The tree-pear (*Opuntia tomentosa*) position in Central Queensland is being watched carefully.

In conclusion, it should be emphasized that the biological control of prickly-pear has been, up to the present, an outstanding success—a success that could hardly have been visualized five years ago.

1. Progress to May, 1929.

The last publication by the Board dealt with the progress of the biological control investigations to May, 1929. At that time, cochineal was generally established throughout the pear areas: it had considerably

* Officer-in-charge of the Commonwealth Prickly Pear Board's investigations.

reduced the height and density of the pear infestation in the heavily-timbered brigalow and belar scrubs, and had brought about very effective destruction of *Opuntia stricta* in Central Queensland. The prickly-pear red spider, *Tetranychus opuntiae*, had co-operated with cochineal in the thinning out of the dense pear in the scrub areas. The plant bug, *Chelinidea tabulata*, was established in enormous numbers at many points, where it was assisting to control the fruit and new growth of the pear. The large-scale distribution of *Cactoblastis cactorum* had been commenced; around some of the centres where the earliest experimental liberations in 1926-27 of this insect had been placed, the destruction of the pest over areas of from a few to 1,000 acres indicated, in some degree, the remarkable progress that might be expected in the near future. But the greatest success had been achieved in the virtual checking of the spread of the pest, a huge increase estimated at nearly 1,000,000 acres annually, as a result of a combination of insect activities and of energetic poisoning methods adopted or enforced by the State prickly-pear organizations.

2. Progress since May, 1929.

The campaign of *Cactoblastis* distribution was carried out on a most extensive scale by co-operation between the Board and State authorities, and was practically completed by the end of 1930, when 3,000,000,000 eggs of this insect had been released throughout the length and breadth of the entire pear area of Queensland and New South Wales, either by direct Government action or through supplies given free of cost to land-owners. So quickly did *Cactoblastis* become established that, by the end of 1931, it could be said that it existed on practically every acre of the tremendous pear infestation of both States; and so rapidly did it increase that widespread collapse of the primary pear followed its activities in every district except the more southern pear area of New South Wales.

Thus the past three years have witnessed a very sudden change in the prickly-pear situation. The success of *Cactoblastis* has been most spectacular. Over enormous areas the original dense pear, that had flourished unchecked for years, has been destroyed. This statement is not intended to convey the impression that the pest has been completely annihilated, for a secondary growth is present in greater or less degree; the re-growth question will be discussed more fully in a special section of this review. As an example of the remarkable progress achieved by *Cactoblastis*, one instance may be given. In August, 1930, the continuous and almost unbroken pear belt along the Moonie River, Southern Queensland, showed for 150 miles no destruction, and so light an infestation of *Cactoblastis* that further distribution was considered. However, the increase of this insect was so rapid that in August, 1932, two years later, 90 per cent. of the primary pear had disappeared. In Queensland, the chief remaining large belt of the two pest pears, *Opuntia inermis* and *Opuntia stricta*, is between Goondiwindi and the Moonie River. Probably 80 per cent. of Queensland's dense primary pear has been destroyed. Very fine results have been achieved in the North-west and the Pilliga State Forest areas of New South Wales; it is estimated that the primary pear has been reduced in all pear districts of that State, excepting the Hunter Valley and Camden districts, by from 50 to 60 per cent.

But as the effectiveness of *Cactoblastis* has increased, that of the other pear insects has diminished. The dense concentrations of *Chelinidea tabulata* have decreased in the past two years to rather scattered numbers. Red spider, as an effective controlling agency, no longer counts. The sphere of usefulness of cochineal has been restricted to the sporadic destruction of new growth. The favorable results at the present juncture can be attributed mainly to the work of one insect, namely, *Cactoblastis*.

3. Reclaiming of the Land.

The Queensland Government immediately took advantage of the first widespread destruction of prickly-pear to promulgate a comprehensive scheme for the development for pastoral, grazing, and agricultural purposes, of land retrieved from the pest by insect agency. The programme is being pushed forward expeditiously. Already 1,514,881 acres of pear land have been re-selected for mixed farming operations, and 1,701,308 acres for grazing, all with development conditions. Ring-barking and falling of the useless timber, the clearing of roads and fence lines, and the erection of fences are proceeding apace. The homes of new settlers have made their appearance. Artificial grasses are being sown as the clearing of the timber progresses. Crops have already been grown successfully.

This marked evidence of progress is an outstanding tribute to the success of the biological control campaign. Within the next few years, great areas of former useless pear land will be brought into productiveness. The many new settlers will mean the growth of townships within the former prickly-pear area. Indeed, at Chinchilla, a new butter factory, shops, &c., already point to greater expansion in the near future.

The development of pear lands, except in the case of a few small areas, has been possible within the past two years only. Hence the work of bringing the reclaimed land into productiveness is as yet in its initial stages.

4. The Other Side of the Picture.

The spectacular destruction of *Cactoblastis* has tended to give the impression that the prickly-pear problem has been completely solved, and that no further research work is necessary. When the extent of the collapse of the primary pear is realized, and when mile after mile of dead and rotting pear is viewed, the tendency to magnify the admittedly wonderful results and to overlook the incompleteness of the destruction is natural. It is therefore necessary to point out in what manner the destruction is incomplete, and to indicate the many aspects of the problem that require continued attention.

(i) *Re-growth*.—Care has been exercised in the foregoing sections of this article to distinguish the destruction by *Cactoblastis* as the collapse of the primary or original prickly pear. But this destruction, spectacular as it has proved, is far from meaning the complete annihilation of the pest. Immediately after the initial collapse of the pear, one sees nothing but dead pear for a few months. The butts and roots, however, have not

been completely destroyed, and when the growing season of the plant, September-December, arrives, re-growth appears. A secondary growth is not peculiar to insect destruction, for it invariably springs up after poisoning operations among dense pear.

In the early days of *Cactoblastis* progress, re-growth was not a pronounced feature. The separate areas of destruction were not extensive, and the insect population in the surrounding standing pear soon overflowed on to the new growth, and brought about its control rapidly. But when the activity of *Cactoblastis* encompassed the collapse of the whole or major portion of the primary pear in a district, the population of the insect suddenly dropped through starvation to very low numbers, and the small residue was quite inadequate to destroy the recurring growth immediately.

The first big wave of re-growth arose in the early summer of 1930. In many areas, it was subjugated during the summer by *Cactoblastis*, which occurred in very large numbers in other portions of the same districts. However, in the Chinchilla district, the vigorous re-growth flourished unchecked throughout 1931; the *Cactoblastis* infestation, at first very light, increased in each succeeding generation, and the new growth was brought under control in the 1932 winter, or nearly two years after its appearance.

Another example of the control of re-growth may be given. In December, 1931, a very dense and vigorous re-growth over several thousand acres on the eastern side of the Mungle Scrub, New South Wales, had reached the fruiting stage. The *Cactoblastis* population, which must have been light indeed eighteen months earlier, was now most satisfactory. Six weeks later, at the end of January, 1932, the whole of this re-growth had collapsed.

Following the great advance of destruction of primary pear, the recurring growth of the 1931 summer involved very considerable areas. Much of this secondary wave of the pest still flourishes, fifteen months later, and in places has recently flowered and fruited. However, *Cactoblastis* is present wherever re-growth occurs. This succulent type of pear is the most favorable medium for the rapid increase of the insect, and there is no reason to expect that the control of existing areas of re-growth will not be brought about within a short space of time. In Central Queensland, for some reason, possibly because of dry winter and early summer months, re-growth has not attained dense proportions, and has not escaped, even if temporarily, the attention of *Cactoblastis*.

In June, 1931, the Board decided that, although the prospects of control by *Cactoblastis* were exceedingly hopeful, it would be unwise to leave the eventual control of re-growth to *Cactoblastis* alone. Hence a programme for the introduction of new strains of cochineal was commenced. Supplies of these insects have been secured from several places in America, and are being reared, with a view to their distribution in the near future. Furthermore, an endeavour is being made to import from North America a particular insect, *Mimorista*, the caterpillars of which feed on young growth solely. With these insects co-operating with *Cactoblastis*, it is hoped that more rapid control of re-growth may be brought about.

(ii) *Natural Enemies of Cactoblastis*.—The future of *Cactoblastis* depends upon the extent of the controlling influences exercised by disease and parasitic agencies. Disease organisms are always present among the larvae, and have at times assumed serious epidemic proportions. However, as outbreaks are sporadic, and appear to be restricted to localities where the larvae are heavily concentrated, diseases are unlikely to bring about control of this insect.

Several native parasites have already turned their attention to *Cactoblastis*, and two have assumed some importance. The investigation of the habits and the controlling effect of these parasites is an important phase of the Board's work. Records of the degree of parasitic attack are gathered from many different localities, in order that the general position in the various districts may be gauged. At present, the control by parasites averages 15 per cent. in Central Queensland and north-west New South Wales, 5 to 10 per cent. in southern and south-west Queensland, and 20 per cent. in the Hunter River district, New South Wales. Thus, parasites are not exercising any important degree of control. In the past two years, the percentage of mortality from parasitic attack has not increased, and there is no reason to anticipate that it will increase in the future. If *Cactoblastis* were ever to be rendered impotent, it would mostly probably be due to the controlling action of parasites. Hence it is essential that scientific observation and investigation should be maintained on this important question.

5. Other Problems.

The re-growth situation, and the extent of parasitism, may be considered the main questions of the future, since they are pertinent to the whole of the prickly-pear area. There are, however, various other problems of a more or less sectional nature.

(i) *The Hunter River Situation*.—Although large-scale destruction of prickly-pear is being secured over the major portion of the infested area, there are certain districts where *Cactoblastis* and other prickly-pear insects have not given entirely the same favorable results. The largest of these sections is the Hunter River Valley, where the dense pear infestation occupies probably 2,000,000 to 3,000,000 acres. The Hunter River situation has been, for the past two years, the subject of a special investigation by the Board. It has been ascertained that the slower progress of *Cactoblastis* is due to a combination of climatic factors and of soil conditions affecting the greater portion of the pear in this area. Until 1931, the results of the extensive distribution of *Cactoblastis* had been disappointing, in that the insect had failed to become established generally. In the past eighteen months, however, *Cactoblastis* has made appreciable progress; areas of destruction, somewhat limited in extent, occur at various points, while a light infestation has become fairly general throughout the district. It is hoped that this progress will continue, and that eventually the Hunter River pear will be brought under control.

(ii) *Tiger-pear (Opuntia aurantiaca)*.—This plant occurs in many places in Queensland and New South Wales. Although the total infestation is not very great, possibly not more than 25,000 acres, it is

increasing rapidly, the rate of spread being much greater than that of the main pest pears. Moreover, the application of poisoning methods has not succeeded in coping with this dangerous plant, which is a very serious pest in South Africa.

Cactoblastis will destroy the upper growth, but not the underground bulb. The recuperative powers of the plant are so great that a few months after its apparent destruction it has regained its former size. When the failure of *Cactoblastis* to control this pest had been ascertained, the Board despatched two officers to South America eighteen months ago to undertake a special investigation of the insect enemies of *O. aurantiaca* and its near allies. A strain of cochineal attacking *O. aurantiaca* has recently been received from the Argentine, where other insects are being studied, with the view to their early introduction into Australia.

(iii) *Tree-pears*.—Extensive areas of tree-pears, *Opuntia tomentosa*, and *O. streptacantha*, more particularly the former, occur in Central Queensland. In the case of *O. streptacantha*, a special strain of cochineal from Mexico is succeeding in destroying the young plants, and is causing damage to the large plants.

As regards *O. tomentosa*, *Cactoblastis* will destroy the young plants, but will not attack the larger plants. The control of the seedling plants would seem assured while *Cactoblastis* is present on *stricta* and *inermis* in the same district, since there is always a suitable food supply for the caterpillars, and the resulting moths will deposit eggs on any young *O. tomentosa* plants that may arise. Hence, the spread of tree-pear is prevented, and the large plants must gradually die of old age. But, in the event of the *O. stricta* and *O. inermis* infestation being eradicated, the control of young tree-pear may cease, and it may become necessary to take further steps toward the introduction of particular insect enemies of this plant.

The Acidity of Cream and the Keeping Quality of Butter made from it, with Special Reference to the Neutralization of Cream.

By *W. J. Wiley, M.Sc.*

From time to time in recent years, various authorities have stressed the need for further research work into problems of the Australian dairying industry. After a very extensive inquiry into all aspects of that industry—the importance of which may be gauged from the fact that it is responsible for a return of some £10,000,000 per annum from butter exports alone—the recent Federal Dairy Investigation Committee reported that, in addition to research work in pastures, diseases, &c., there was need “for a research service in dairy bacteriology and biochemistry which would investigate problems of a more fundamental character which are common to all States.”

It had accordingly been hoped that with the completion of Mr. Wiley's work on the prevention of wood taint in butter, it would have been possible to provide the necessary funds for further work on other problems connected with butter production. One such problem is the determination of the best degree of acidity to adopt in the case of butters intended for the export trade. As a preliminary to some work on that matter, Mr. Wiley has spent some time reviewing the literature dealing with the effect of acidity on the keeping qualities of butter. Unfortunately, it has not been possible for the Council, with its limited resources, to finance further work, but, as the above-mentioned review may be of some interest, an article based on it has been prepared by Mr. Wiley, and is published below. Those specially interested would be able to peruse the more detailed review at the Council's head office.—*Ed.*

Summary.

1. The results of some of the more important of the published results on the acidity of cream and the keeping quality of butter prepared from it have been reviewed.
2. The subject of cream neutralization has been briefly reviewed, and some theoretical aspects of the subject discussed.
3. The results of a recent examination of 70 samples of butter are given, and show the lack of standardization in the acidity.

1. Introduction.

In the last year, 91,086 tons of butter, valued at over £10,000,000, were exported from Australia, and the greater part of this would not reach the ultimate consumer's table until at least two months after manufacture, and might even be held for a considerably longer period. The necessity of Australia manufacturing butter of particularly good keeping quality is thus obvious.

It speaks volumes for modern methods of manufacture and control that most of these export butters deteriorate very little during the necessary storage. The gross causes of deterioration have been studied and largely eliminated, but there is still considerable discussion over the more detailed aspects of the subject. For instance, although the fact that high acid butters do not hold up on storage is well known, the exact degree of acidity desirable is not so well established.

The acidity of the butter is a factor influencing the chemical changes taking place even at cold storage temperatures. A large amount of practical experimental work has been published on this subject, and probably even more not published. Very little, however, has been done on the theoretical aspects, and beyond such vague generalities as that acidity favours fat hydrolysis, thus leading to greater susceptibility to oxidation, the precise reasons for the profound effect of what is after all a quite small acidity in even the most acid butters have not been established. Practical work has been stimulated by the fact that low acidity of the butter and the choicest flavour of the fresh product are, to a certain extent, antagonistic. Butter churned from sweet cream lacks the flavour and aroma-producing substances which many people consider essential for the choicest product. When these are developed by cream ripening, the acidity inevitably produced spoils the keeping quality of the butter. In some factories where sweet cream is received, this has led to the practice of ripening and then neutralizing the acidity to ensure good keeping quality and still leave some of the flavour of the ripened cream butter. Where the cream is received already sour, neutralizing is essential to obtain keeping quality.

It has been mentioned that although the deleterious effect of high acidity is well known, the most desirable acidity is not so well established, and wide differences of opinion exist among butter-makers on the subject. It is the purpose of this article to describe briefly some of the more important experimental work which has been published on the subject. Unfortunately, most of that work which gives full experimental details has been done in other countries, and may not be applicable in detail to Australian conditions.

Obviously it is the acidity of the butter that affects its keeping qualities, and the only control over this the butter-maker has is the acidity of the cream, so that practically all the work has been done on the acidity of the cream at churning time. The experiments divide themselves into two groups, those where the cream acidity has been obtained by ripening, and those where the cream has first become sour and then neutralized to the desired figure. The best acidity for keeping quality may not necessarily be the same for the two methods.

2. The Keeping Quality of Butters from Un-neutralized Creams of various Acidities.

As early as 1890, several authors had reported the superior keeping qualities of sweet cream butter. The work of Rogers and associates (1909-1913) definitely established this, and indicated the factors influencing the changes during cold storage of butter. The oxygen content of the butter was found to decrease, and when excess air was worked into the butter, deterioration was accelerated. It was suggested that the off flavours produced might be at least in part due to oxidation of lactose, and this would be accelerated by lactic acid, because of inversion of the lactose. The catalytic effect of traces of copper and iron was fully established. It should be noted that Rogers found that lactic, hydrochloric, or acetic acids added to bring the acidity from 0.22 to 0.45 per cent. to sweet pasteurized cream of acidity 0.13 per cent. caused

similar deterioration to that produced by lactic acid from natural ripening. The increased oxidation due to acidity, therefore, is not a specific effect of lactic acid, but rather an effect due solely to acidity.

Rogers also found that high acidity and salt concentration led to the taint of fishiness and Supplee (1919), Cusick (1920), and Sommer and Smit (1923) confirmed this, and showed that trimethylamine, which is produced by the hydrolysis of lecithin, is responsible for the fishy flavour. O'Callaghan (1907) claimed that salting had nothing to do with fishiness, and that it was due to the mould *Oidium lactis* growing in conjunction with *B. acidi lactici*. It is interesting to note that he stated that "the terror of the Australian butter grader is that form of decomposition which is accompanied with a fishy flavour." With the subsequent adoption of neutralization and pasteurization of cream, this taint has lost much of its importance in Australia.

Dyer (1916) studied the chemistry of the deterioration in cold storage butter by measuring the change in composition of the gas enclosed within the butter. He found very little change in the oxygen content of butter made from sweet cream or sweet cream plus starter (0.25 per cent. acidity) after storing six months at 0 deg. F. When the cream was acidified with lactic acid to an acidity of about 0.7 per cent. before churning, there were pronounced changes in the gases on storage, the oxygen content decreasing. Pure butter-fat did not absorb appreciable quantities of oxygen on storage, while butter intentionally made to contain more than the normal proportion of non-fatty solids absorbed oxygen. In none of the experiments were the chemical constants of the butter-fat appreciably altered. Dyer concluded that these results indicate that the non-fatty solids rather than the fat are concerned with the deterioration of storage butter from acid cream. It is possible, however, that the non-fatty solids and acidity exert a catalytic effect in the oxidation of the butter-fat, and that their presence is necessary for appreciable oxidation under the conditions. For instance, Briggs (1931) found that lactic acid has a pro-oxidative effect on butter-fat, although he found curd to have an anti-oxygenic action. The absence of change in the analytical constants of a fat cannot be taken as proving that there has not been sufficient chemical action to affect the flavour materially. Changes in flavour can be detected long before there is any appreciable alteration in the usually determined fat constants. Dyer's results, however, definitely showed the more rapid oxidation of some butter constituent with increased cream acidity.

Hunziker and Hosman (1917), in a study of tallowy butter, ascribe this fault to glycollic acid produced by the oxidation of glycerol or lactose. They do not state that this fault is most common in butter from high acid cream, but claim it to be produced when the butter is made from an alkaline cream. It may here be mentioned that tallowy flavours are now generally considered to be due to oxidation of the fat, commencing at the double bonds in oleic or linolenic acids present, although the exact mechanism is not thoroughly understood. While this is undoubtedly true for a pronounced tallowy flavour, accompanied by bleaching of the fat, it is by no means established that the comparatively mild taints, sufficient, however, to degrade the butter, and termed "tallowy," are due to the same cause. These can be detected before

the butter-fat gives a positive Kreis reaction, and this, in turn, is given during the period of induction of the fat oxidation, before active uptake of oxygen has commenced.

Grimes (1923) did not find the butter from ripened cream invariably deteriorated appreciably when stored six to seven months at -6°F . The cream was ripened to 0.5 to 0.61 per cent. acidity, and salted from 1.5 to 2.1 per cent. The good keeping quality of some of this butter is surprising. He concludes that "the occurrence of erratic decreases in score of butter made from ripened cream which rarely occurs when the cream is not ripened suggests that the deterioration of butter made from ripened cream is due to some as yet undetermined cause which may be aided in its action by the lactic acid produced during the ripening of the cream."

Hunziker (1927), in discussing cream ripening, states that "the danger of chemical deterioration of salted butter due to cream ripening may be not only minimized, but entirely avoided by so adjusting the per cent. acid in the cream, and the time and temperature of the ripening process as to ensure relatively low acidity, not to exceed 0.32 per cent. in the cream at churning time." With unsalted butter, the acidity may be 0.4 to 0.5 per cent. The figure 0.32 per cent. for salted butter is stressed throughout the book, and is considered a quite safe maximum. Although the subject is discussed at length, experimental results justifying such a comparatively high figure are not given.

Haglund and Waller (1922-1929) investigated the manufacture of butter under Swedish conditions. They confirmed the deleterious effect of high acidity on keeping quality. However, the acidities appear to be much higher than is generally considered desirable in this connexion, as they ranged up to 0.8 per cent., but the storage periods were comparatively short, namely, 20 days. They found that washing of the butter could not appreciably affect the acidity of the butter-fat or serum, and that the pH of the serum was mainly determined by the acidity of the cream.

White, Trimble, and Wilson (1929) report a complete series of experiments carried out with the object of determining just what is the most desirable acidity at which to churn cream where the butter is to be stored. Only salted butter was considered, the salt varying from 1.8 to 2.8 per cent.

In different series of experiments, the following methods of standardizing the acidity were used:—Addition of lactic culture and subsequent pasteurization; pasteurizing and then adding culture; pasteurizing followed by ripening; and ripening and neutralizing followed by pasteurizing. From their own results and examination of many commercial butters, the authors conclude that the quality of butter after storage is proportional to the acidity of the cream from which it was churned. When the butter was stored at 0°F ., the decrease in score, even after eight months, was very slight for acidities up to 0.31 per cent. The authors, however, state that there appears to be no advantage in making butter for storage from cream with an acidity as high as 0.31 per cent. Ripening cream with a lactic culture, even to low acidities, improves the score of the butter when fresh, but the improvement was usually lost during storage.

Some work has been published in which the hydrogen-ion concentration of the butter, rather than the titratable acidity of the cream, has been considered. Parfitt (1927) reports the results of the examination

of 186 samples of cold storage butters. The pH was found to increase during a storage of four months, but Parfitt does not correlate any decrease in score of the butter with the original pH. He found values ranging from 4.6 to 7.2. Cream neutralized to an acidity of 0.1 per cent. gave a butter of pH 7.2, to 0.2 per cent. a pH of 6.6, and to 0.3 per cent. a pH of 6.0. His determinations were made by making a 1 in 10 dilution of the melted butter and using this for a colorimetric estimation. The aqueous phase of the butter was thus diluted at least 1 in 60 before measurement, so, although the results may be comparative, little importance can be attached to the absolute values.

Guthrie and Sharp (1931), in an investigation of the effect of pH on churning time, made some interesting observations. They covered a wide range of acidities, far greater than would ever occur in practice. The fresh cream was adjusted to the desired pH by the addition of acid or alkali. The experimental butters were stored for seven months at 0 deg. F., and the results are shown diagrammatically thus:—

<i>Flavour.</i>														
sharp acid cheesy			off flavours stale fishy			best flavours trifle stale			soapy stale alkaline					
tallowy														
pH	1	2	3	4	5	6	7	8	9	10	11	12	13	14
white								yellow					white	
<i>Colour.</i>														

The range pH 6 to 9 for best flavours is interesting. A cream of pH 8 to 9 would be very much over-neutralized, but no mention is made of alkaline flavours in the butter (compare the results of Barlow mentioned later). However, the authors point out that "it should be remembered that while the best flavour was found in the range from pH 6 to 9, the range of best flavour might be quite different if the cream had first been allowed to sour and had then been neutralized."

Hunziker, Cordes, and Nisson (1931) suggest the possibility of using pH as a test to indicate the suitability of butter for cold storage. They say that preliminary studies indicate a correlation between the pH of butter and its keeping quality. Their paper, however, is mainly devoted to the determination of pH of butter, and its relationship with the pH of cream and buttermilk. Nisson (1931) discusses the pH of butter and its relation to titratable acidity.

The papers so far discussed are confined to the keeping quality of butters churned from creams of varying acidities, but have not considered the neutralization of cream before churning when the cream has already developed excessive acidity. Practically all the authors agree that salted butter from high acid cream generally suffers in keeping quality, but this is not invariably the case. There appears to be some unknown factor which, in conjunction with high acidity, leads to deterioration in cold storage. When a large number of samples have been worked with and the results averaged, the loss in score during storage seems to be proportional in any increase in acidity over about 0.15 per cent. However, up to about 0.3 per cent., the loss appears to be negligible, and may be offset by improvement in the original score of

the butter. This upper limit of 0.3 per cent. appears to be well established by the papers quoted. Most of the papers deal only with salted butter, and there seems to be room for further work with unsalted butter. From the limited amount of published work, it would appear that this keeps better when made from ripened cream. Practical experience in Australia has not always confirmed this. A large amount of unsalted butter is now used in the manufacture of reconstituted milk and cream, and for this purpose, the flavour imparted by ripening cream is undesirable.

3. The Neutralization of Cream for Butter-making.

With the advent of the farm separator, and the consequent great increase in the supply of sour cream to the butter factory, the process of cream neutralization became common. At first, there was a tendency to regard neutralization as a form of adulteration, and some of the earlier papers are written with the object of justifying the practice, and showing the small effect it could have on the composition of the butter.

O'Callaghan (1915) gives a general discussion on the advantages and disadvantages of pasteurization and neutralization of cream under Australian conditions at that time. He finds it "advisable to neutralize to something below 0.2 per cent.", and states that neutralization with sodium bicarbonate greatly reduces food flavours by aeration. Ramsay (1915) discusses the possible reactions when sodium bicarbonate and calcium hydroxide are added to sour cream, and gives the results of analyses showing little difference in composition of butters made from neutralized and raw creams. McInnes and Ramsay (1918), and O'Callaghan and Ramsay (1918), describe the use of lime as a neutralizing agent. They also describe experiments where sodium peroxide was used as a neutralizer. It is not surprising that they found the butter had a "greasy taste, inclined to be tallowy." Ramsay (1920) reports the results of numerous laboratory and factory experiments on the neutralization of cream with sodium bicarbonate and lime. The results are interesting in showing the tremendous variations which can be obtained in factory work in the results of the neutralization. Complete neutralization with lime was never found, and very erratic results obtained with sodium bicarbonate. With the latter reagent, more complete neutralization was obtained with the flash system of pasteurization.

McInnes (1921) reports some experiments where a mixture of sodium bicarbonate and lime was used for neutralizing. Only about 60 per cent. of the theoretical effect was obtained, but the author does not comment on this result.

Valentine (1925) also, in a general article on neutralization with sodium bicarbonate, mentions some of the difficulties encountered in obtaining exact results. He says the addition of soda solution to the cream does not reduce the acidity more than 0.02 or 0.03 per cent. until heat is applied. After a certain amount of soda has been added to the cream, an extra quantity increases the acidity instead of reducing it. This is sometimes the case when neutralizing to a low degree of acidity, as is common in New Zealand (about 0.1 per cent.).

Barlow (1922) describes some interesting experiments on the effect of over-neutralizing the cream, and concludes that butter made from cream neutralized as low as 0.2 per cent. alkaline with sodium bicarbonate had no objectionable alkaline flavour, and that objectionable

alkaline flavours are due to faulty neutralization processes rather than excess of neutralizer. It is interesting to note that Parfitt (1927) found that butters criticized for having an alkaline flavour showed a pH on the acid side, averaging 5.35 on entering storage, and 6.38 on leaving store after four months. This increase during storage was considerably greater than that shown by any other type of butter. Evidently, some abnormality in ionic conditions in the butter serum was responsible for the "alkaline" flavour. These results and those of Guthrie and Sharp (1931) confirm Barlow's finding that a neutralizer flavour is not necessarily due to over-neutralizing.

Hunziker (1927) fixes 0.25 per cent. as the best figure to aim at in neutralization, so that there will be no danger of exceeding an acidity of 0.32 per cent. in the cream at churning time, the latter being the figure he considers the danger point when the keeping quality of the butter is considered. He discusses the various neutralizing agents that have been used, and states that the neutralizing action of the various soda neutralizers (carbonate, bicarbonate, sesquicarbonate, and proprietary mixtures) is exactly as calculated by chemical equations assuming a simple combination with lactic acid. With lime, he states that the neutralization obtained is approximately 80 per cent. of that calculated.

Davell (1929) made numerous small-scale experiments on cream neutralization in South Africa, where the practice does not appear to be general. He found no advantage from neutralizing creams which were below 0.4 per cent. acid, and even when the cream acidity was above 0.5 per cent. the improvement gained by neutralizing was not particularly marked. The acidity was reduced to 0.25 per cent. The results are interesting as showing a recent investigation where generally accepted practice was not upheld. However, it appears from the figures given that South African and Australian grading must be entirely different, and probably in many experiments, factors other than acidity were causing such serious deterioration that the effects of acidity were overshadowed.

Walts and Libbert (1930) experimented with eleven neutralizers, including sodium bicarbonate, sodium carbonate, four proprietary mixtures of these, and five lime-magnesia mixtures. A complete analysis is given of these. In all cases, the use of the neutralizer improved the score of the fresh butter, but in no case was there sufficient difference to justify a conclusion that any one particular neutralizer had any distinct advantage over any of the others so far as the flavour of the butter was concerned.

The majority of the work published, and the results obtained in countries where neutralization is a regular procedure, show that the keeping quality of the butter is undoubtedly enhanced by the practice. Most authors favour a neutralization to 0.2 to 0.25 per cent. acidity. There is no doubt, however, that many experienced butter-makers consider neutralization to a lower point to be desirable, and many factories have for years neutralized to about 0.1 per cent. acidity with good results. The majority of the papers published are American, and the authors have generally considered there is a danger of neutralizer flavour when a low acidity is adopted. When the original acidity is high, they recommend a smaller reduction than when low, to obviate the necessity of adding a comparatively large quantity of neutralizer.

However, very few results are quoted where the neutralization has been carried below 0.2 per cent. Barlow's results are interesting, as he made butter scoring as choicest when the cream had been made actually alkaline with sodium bicarbonate. It has been recommended to neutralize to 0.1 per cent. when the cream had an acidity of 0.35 per cent., and when of acidity over 0.5 per cent. to neutralize to 0.04 per cent. (Stenning, 1932), this being the reverse of the procedure common in America. However, experimental details of the advantages to be gained have not been given. There appears to be need of a complete and careful investigation to establish the most desirable acidity to which to neutralize the cream. Admittedly good butter can be made over a fairly wide range of acidities, but with the most desirable figure more firmly established the way would be open to the manufacture of a better standardized product.

The rate of reaction of the various neutralizing agents and the extent to which they reduce the acidity as compared with what might be expected, assuming a simple reaction with lactic acid, are questions which frequently arise. A few authors claim to have obtained the theoretical reduction with all of the common neutralizers, including lime, but when the subject has been carefully studied, quantitative results have never been obtained (see particularly Ramsay (1920) and Valentine (1925)).

4. Notes on the Theory of Cream Neutralization.

The dairy industry has adopted its own arbitrary method of expressing the "acidity" of its products. The acidity of milk and cream is always measured by titrating with a standard solution of sodium hydroxide, using phenolphthalein as an indicator, and in British and American countries the value so obtained is calculated as percentage lactic acid. While the use of phenolphthalein as indicator is most desirable, on account of the comparatively good end point obtained in the titration, it is unfortunate in that it has given rise to the too commonly held impression that a milk or cream showing a titratable acidity is necessarily "acid", and that the contents of "acid" is proportional to the figure obtained in the titration. This, of course, may not always be the case. The end point obtained with phenolphthalein in the titration of milk or cream occurs at about pH 8.5, i.e., distinctly alkaline. Milk and cream are well buffered solutions, and require an appreciable quantity of alkali to bring them from the true neutral point of pH 7 to that of the phenolphthalein end point. Moreover, the acid-base system is so complex that different procedures in titration, such as dilution of the sample, lead to different results for the acidity. The phenolphthalein end point, although better than that given by other indicators, is not particularly sharp, and this, coupled with the nature of the fluid titrated, leads to difficulties in the exact control of acidity when low figures are desired.

A typical sour cream of titratable acidity 0.40 per cent. would have a pH of approximately 4.8. Its acidity before souring commenced would be about 0.11 per cent., and the lactic acid developed 0.29 per cent., assuming a simple lactic fermentation. At pH 4.8, the lactic acid ($pK = 3.8$) would be already 90 per cent. neutralized, so that greater part of the acidity measured in the titration is due to the other milk constituents present which buffer between pH 4.8 and pH 8.5.

These are the protein, chiefly casein, and the phosphates, citrates, and carbonic acid. The reactions are greatly influenced by the calcium and magnesium present, because of the low solubility of their phosphates and the slight dissociation of calcium citrate and caseinate.

When the acidity is measured by titrating with caustic soda, there is considerable fading at the end point, showing equilibrium is not established. This is due to the slow precipitation of tricalcium phosphate, as in the presence of calcium, phosphoric acid titrates to phenolphthalein as a tribasic acid and not as a dibasic acid as in simple solutions. When lime is used as a neutralizing agent, and the cream pasteurized, the tricalcium phosphate precipitation is more complete, and thus a lesser degree of neutralization is obtained than would have been expected from the caustic soda titration. Also Palmer and Richardson (1925) obtained the following results for the base binding power of casein:—

pH.	Gram equivalents of base-bound $\times 10^{-4}$. per gram of casein.	
	NaOH.	Ca(OH) ₂ .
6	8	32
7	58	70
8	76	88

At pH 6, the higher quantity of calcium bound would correspond to about 0.05 per cent. of lactic acid in the titration, and at pH 7 to about 0.025 per cent. Thus, both the reaction with the phosphates and casein lead to a lesser neutralization when using lime than is to be expected from the soda titration.

When sodium bicarbonate is used as a neutralizer, it is obvious that the full reduction in acidity cannot be obtained before the cream is pasteurized. Sodium bicarbonate is "neutral" to phenolphthalein; so, in the cold, complete neutralization of the cream to this indicator could never be obtained. When the cream is pasteurized, carbon dioxide is lost, and the reaction approaches that obtained in the titration with sodium hydroxide. When the holding system of pasteurization is used, however, the loss of carbon dioxide is probably never complete, and the theoretical reduction in acidity is not obtained. The carbon dioxide is more completely driven off in flash pasteurization, so a lower acidity is found in the cream.

The carbon dioxide originally present in the cream behaves in the same way. If the sample which is titrated is not boiled, this carbon dioxide is estimated in the acidity, but after pasteurization of the main bulk of cream the carbon dioxide is driven off and the neutralization obtained may be greater than was calculated on. It has been suggested that other volatile acids produced by bacterial action sometimes occur, and in a similar way lead to errors in neutralization. This is hardly likely, however, as the only probable acids, besides being much less volatile than carbon dioxide, are considerably stronger and at the pH at which the cream is pasteurized would be held back as salts.

Even after pasteurization, it is possible that equilibrium is not fully established. It is well known that a slight flavour of neutralizer in freshly churned butter generally disappears after a few days. The

results of Parfitt (1927) are suggestive. He found that butters criticized for alkaline flavour were really acid when examined for pH, but that the pH increased during storage by slightly over one unit, whereas with other butters the increase was about 0.3 units.

From the above considerations, the erratic behaviour often noted in cream neutralization is not surprising.

5. Results of an Examination for Acidity of Victorian Butters.

The large variation in acidity of the butters now exported from Australia is shown by the following results, which were obtained on 70 samples of butter recently examined. These were obtained for a different investigation, by Messrs. Loftus Hills, and Scharp of the Victorian Department of Agriculture, and the author is indebted to these investigators for the opportunity of making the following measurements. With a few exceptions, the butters would all have been made from neutralized cream. The measurements were made on samples approximately one week after churning, and which had been kept in a chilled, but not frozen, state. The butters were all of first or choicest grade, and fell into the following groups:—

Grade for flavour.	No. of samples.	Per cent of total number of samples.
39	3	4
40	8	12
41	24	35
42	27	39
43	7	10

For convenience, the results are grouped in the following table according to the pH range of the samples.

pH range of serum.	No. of samples.	Mean acidity of butter as per cent. lactic.	Mean acidity of serum as per cent. lactic.	Mean acid value of fat	Mean peroxide in fat N (c.c. $\frac{N}{500}$ $\text{Na}_2\text{S}_2\text{O}_8$ per gram of fat).	Mean grade for flavour maximum 50 points.
5.2-5.39	1	0.0500	0.250	0.63	1.1	40
5.4-5.59	0	..	..	..	..	..
5.6-5.79	2	0.0295	0.164	0.48	0.83	41.25
5.8-5.99	7	0.0249	0.104	0.57	0.79	41.14
6.0-6.19	6	0.0208	0.086	0.50	0.76	41.58
6.2-6.39	16	0.0154	0.073	0.60	0.87	41.54
6.4-6.59	10	0.0132	0.060	0.53	0.63	41.61
6.6-6.79	4	0.0108	0.039	..	0.66	41.25
6.8-6.99	7	0.0090	0.037	0.54	0.56	41.57
7.0-7.19	12	0.0073	0.023	0.56	0.60	41.54
7.2-7.39	3	0.0063	0.014	0.62	0.48	41.50
7.4-7.59	1	0.007	0.007	0.41	0.4	41.5
7.6-7.79	1	Alkaline	Alkaline	0.26	0.2	41
	70					

The following conclusions may be drawn from these results:—

1. The range of acidities is quite large. There is a distinct grouping of the samples about pH 6.3 and 7.1. Other evidence indicates that these figures correspond very approximately to acidities of 0.18 and 0.09 per cent. respectively in the cream.

2. There is a distinct correlation between the pH of the butter serum and titratable acidity of the butter and the serum. The pH of the butter serum was determined by the quinhydrone electrode on the undiluted serum, the butter acidity by the method of Nissen (1931) using $\frac{N}{50}$ sodium hydroxide, and the titratable acidity of the serum by titrating 10 cc. diluted to 100 cc. with $\frac{N}{50}$ sodium hydroxide.

3. There appears to be no correlation between the acid value of the fat and the acidity of the butter, except perhaps with the two most alkaline butters, but as only two samples were examined any conclusions would be doubtful. It is possible that the serum has been sufficiently alkaline to neutralize some of the fatty acid of the fat phase.

4. There is a correlation between the peroxide of the fat (Lea, 1931) and the acidity of the butter. If it can be established that this peroxide content is a true measure of the incipient oxidation of the fat and the onset of tallowiness, this result is important. The examination after three months' storage should give more conclusive results. The coefficient of correlation between the acidity and peroxide is — 0.51. As other factors, such as presence of copper and iron, and exposure to light, have been neglected, this correlation with acidity of the aqueous phase is interesting.

5. There appears to be no connexion between the grading of the various butters when fresh and their acidities. Except in the extreme instances where there were very few samples, choicest butter was found in all the groups. It is apparent that neutralization can be carried to quite a low degree without adversely affecting the flavour. In fact, from the results of these butters, acidity between say pH 5.6 and 7.4 seems to be one of the minor factors affecting the grade of the butter when fresh.

These results are included here to show the large variation in acidity obtained in good quality butter. If the most desirable acidity could be firmly established the way would be open for the manufacture of a more uniform product of possible better keeping quality.

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A Parasitological Field Trial on "Gundowringa," New South Wales, 1932.

By I. Clunies Ross, D.V.Sc.* and N. P. Graham, B.V.Sc.†

During 1931, field trials were initiated by the Division of Animal Health in order to investigate different aspects of the problems involved in controlling losses from internal parasites of sheep. This work forms part of the programme that is being undertaken by the Division under the Australian Pastoral Research Trust-Empire Marketing Board scheme (see this *Journal*, August, 1931, p. 134). The trials themselves are being carried out with the kind co-operation of Mr. D. E. Donkin, of "Meteor Downs", Springsure, Queensland; Mr. C. E. Prell, of "Gundowringa", New South Wales; and Mr. K. Brodribb, of "Frodsley", Tasmania, all of whom have very greatly facilitated the experiments by making the necessary experimental sheep and land available. The article that follows discusses the second year's work at "Gundowringa". The results of the first year's work at that station were published in a previous issue (February, 1932, p. 31).—Ed.

Summary.

1. Corriedale ewe lambs, grazed on improved pasture, both with and without anthelmintic treatment, and with and without rotation of pastures, at the rate of 2½ and 3 sheep per acre, respectively, made very much greater average gains in live weight, and produced from 1½ to 2½ lb. more wool per head than sheep on natural pastures at the rate of one sheep per acre.

2. The average gain in live weight was 14 lb. per head and per acre on natural pasture; while on improved pasture, without rotation, it was 49 lb. per head and 122.5 lb. per acre, and on improved pastures, with rotation, it was 51 lb. per head and 153 lb. per acre.

3. Sheep on natural pasture produced, on an average, 9 lb. 2 oz. of wool per head and per acre, while on improved pasture up to 11 lb. 13 oz. per head and 35 lb. per acre were produced.

4. The sheep on improved pasture, and treated with an anthelmintic (carbon tetrachloride) at monthly intervals did not show any increase in body weight in comparison with sheep on similar pasture but not treated with an anthelmintic.

5. The sheep on improved pasture, treated with an anthelmintic (carbon tetrachloride), showed a material increase in the weight of fleece produced per head in comparison with untreated controls.

6. The effect of improved pastures on wool character was to produce a slight lowering in the count, but such wool was estimated to give as high, or higher, percentage clean scoured yield as that from natural pasture, and was of better staple length.

1. Introduction.

In 1931, the Council for Scientific and Industrial Research conducted a field trial on "Gundowringa" (20 miles north of Goulburn, New South Wales), to obtain evidence as to the effect of heavy stocking on improved pastures in increasing the risk of parasitic infestation. The results of this trial tended to show that, owing to the improved condition of sheep on such pastures, any increased risk of exposure to parasitism was more than compensated for by the greater resistance

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of sheep to infestation. The trial about to be described was designed to offer confirmation to that of 1931, and had, in addition, the object of determining the effect of improved pasture in altering wool character.

Five groups of sheep were employed, as follows:—

1. Lot 1 comprised 50 sheep, grazed on natural pasture, at the rate of one sheep per acre. No treatment for parasites was given throughout. (Though this pasture had not been artificially improved, it was in part considerably better than the general natural pasture, owing to the fact that it had been a sheep-camp before the original property was subdivided).

2. Lot 2 comprised 50 sheep, grazed on improved pasture, at the rate of $2\frac{1}{2}$ sheep per acre. No treatment for parasites was given. The "improved pastures" consisted of pasture that had been sown with subterranean clover and English meadow grasses, and fertilized every second year with 1 cwt. of superphosphate per acre.

3. Lot 3 was identical with Lot 2, except that all sheep were treated each month with 2 ccs. of carbon tetrachloride in 3 ccs. of liquid paraffin.

4. Lot 4 comprised 60 sheep, run on improved pastures, which were subdivided so that each unit was stocked for one month and then unstocked for three. The average stocking of the whole area was three sheep per acre.

5. Lot 5 was identical with Lot 4, except that all sheep received monthly treatment with carbon tetrachloride, as in the case of Lot 3.

Parasitic Conditions at the Beginning of the Trial.—Prior to the commencement of the trial, five sheep of the same age and type as those selected were examined *post-mortem* to determine the type of worm infestation present. It was found that the degree of infestation varied greatly in individual lambs, being quite heavy in certain small, under-sized animals, but very light in those which were well grown. The species represented were *Haemonchus contortus* (the large stomach worm), *Ostertagia* spp., principally *O. circumcincta* (the brown hair worm, or medium stomach worm), *Trichostrongylus* spp. (the small stomach and intestinal worm), *Nematodirus filicollis* (the thin-necked intestinal worm), and in the large bowel *Chabertia ovina* and *Oesophagostomum venulosum*.

2. Conduct of the Trial.

The trial was begun on 8th January, 1932. The trial sheep were selected from Corriedale flock ewe lambs, 4 to 5 months old. The lambs were classed beforehand, and 270 selected as nearly equal in weight and condition as possible, any exceptionally large or small lambs being discarded. The weight of each lamb was recorded, and it was found that the average weight of all five lots was from 65 to 66 lb.

All sheep were weighed subsequently, at monthly intervals, and Lot 3 and Lot 5 were drenched with carbon tetrachloride. In order to observe, if possible, any marked change in the degree and type of parasitic infestation, faecal samples were cultured from five sheep in each group, the animals being chosen at random, at each monthly weighing.

In the hope of setting up initially some definite degree of infestation in all sheep with what is probably the most important species, *Haemonchus contortus*, each animal at the start of the trial was drenched with a dose of 100 *H. contortus* larvae by syringe.

The trial was terminated on 24th October, that is, after some nine and a half months. At this time, the sheep were shorn, individual fleece weights being recorded and the fleeces classed for quality and general character.

At the end of the trial, three sheep in each of Lots 1, 2, and 3, and five in Lot 4 were killed and examined *post-mortem* for parasites.

Climatic and General Conditions during the Trial.—The rainfall during the trial was as follows:—

				(Inches.)
January	..	..	..	—
February	..	..	..	.64
March ..	..	..	..	4.62
April ..	..	..	..	2.19
May ..	..	..	..	.83
June ..	..	..	..	3.22
July ..	..	..	..	2.68
August ..	..	..	..	3.08
September	..	..	..	1.59
October	..	..	..	1.86
Total	..	..	..	20.71

Owing to the lack of rain in January, and the low fall in February, it was not possible to maintain at the start the monthly rotation of Lots 4 and 5, as the available small dams of water gave out. In the heavily-stocked improved pastures, clovers, and grasses were eaten well down, but the sheep of these lots compared quite satisfactorily with the lot on the more lightly-stocked natural pasture.

Following good rains in March, all four improved pasture lots began to make rapid weight gains, which were continued throughout the very severe winter, during which very low temperatures, with occasional falls of snow and sleet were experienced up to late August. In contrast, Lot 1, on unimproved pasture, showed no material weight gains until September, these gains becoming marked in October.

Parasitic Infestation.—Faecal cultures on 8th February, one month after the trial began, gave a considerable proportion of *H. contortus* larvae in all groups.

	Lot 1 showed 57 to 96 per cent. of <i>H. contortus</i> .				
	Lot 2	„	74 to 98	„	„
	Lot 3	„	53 to 78	„	„
	Lot 4	„	40 to 99	„	„
the	Lot 5	„	6 to 71	„	„

Faecal cultures, on 8th March, prior to the heavy rains of that month, showed—

Lot 1	showed	92 to 99	per cent.	<i>H. contortus</i> .
Lot 2	„	82 to 100	„ „ „ „	
Lot 3	„	0 to 39	„ „ „ „	
Lot 4	„	78 to 92	„ „ „ „	
Lot 5	„	0 to 2	„ „ „ „	

It will be seen that two successive monthly treatments in Lots 3 and 5, under dry conditions, had effected a very striking reduction in the degree of infestation with *H. contortus*. Following the March and later rains, faecal specimens became diarrhoeic, and were less satisfactory to culture, but in all lots, whether treated or untreated, the degree of infestation with *H. contortus* diminished during the later winter months, only a minority of animals from which faeces were cultured showing such infestation. In September, the number of animals showing *H. contortus* again rose, but, owing to the unsatisfactory nature of cultures, it cannot be said definitely how the general degree of infestation in the several lots compared, but all appeared light.

3. Results of Trial.

(i) *Body Weight.*

At the conclusion of the trial in October, the average body weight of the five lots, and the average gain per head, and average gain in live weight per acre in the five lots, were as follows.—

Lot.	Average Weight in Pounds (October).	Average Gain Per Head in Pounds.	Average Gain in Live Weight Per Acre in Pounds
1	80	14.5	14.5
2	114.5	49.0	122.5
3	115.5	49.0	122.5
4	117.5	51.0	153.0
5	116.5	51.0	153.0

It is seen that very striking increases occurred in all improved pasture lots, as compared with Lot 1, but that Lots 2, 3, 4, and 5 showed very little difference in their average weight gains. Dr. Carr Fraser has examined statistically the detailed figures from which the above table was drawn up, and finds no significant difference between any of these four lots. It is apparent (a) that Lot 2 and Lot 4, on improved pasture, untreated, compare more than favorably with Lot 1, and (b) that any increased risk of parasitism in the absence of treatment on heavily stocked improved pastures has been more than offset by the greatly improved nutrition of these animals. So far as the comparison of treated with untreated lots (Lots 2 and 3 and Lots 4 and 5) is concerned, medicinal treatment for parasites in no way influenced weight gains.

(ii) *Fleece Weights.*

The average fleece weights per head of each group, and fleece production per acre, as determined by weighing each fleece, were as follows:—

Lot.	Average Fleece Weight Per Head	Fleece Weight Per Acre.
1	9 lb. 2 oz.	9 lb. 2 oz.
2	11 lb. 3 oz.	27 lb. 3 oz.
3	11 lb. 13 oz.	29 lb. 8 oz.
4	10 lb. 14 oz.	32 lb. 10 oz.
5	11 lb. 10 oz.	34 lb. 14 oz.

The figures for fleece production represent eleven months' wool growth, the lambs having been shorn previously on 21st November, 1931, while for only nine and a half months during the actual trial had they been grazed under varying conditions. It is seen that all four improved pasture lots produced more fleece than the natural pasture group. So far as the effect of medicinal treatment is concerned, Lot 2 is comparable with Lot 3, and Lot 4 with Lot 5. Dr. Carr Fraser has found that the probability of the difference in production of Lot 2 and Lot 3 being due to chance is 1 in 80, this being almost significant, while the difference between Lot 4 and Lot 5 is undoubtedly significant. It is seen, therefore, that though the body weights of these groups did not differ significantly, medicinal treatment was able to bring about a significant increase in wool production, even though parasitic infestation at no time was really heavy, while it is probable that *H. contortus* was the only parasite the incidence of which was markedly affected by the treatment.

(iii) *Quality of Wool.*

So far as the quality of wool in the several lots was concerned, attention was directed towards the elucidation of the influence of pasture improvement in affecting wool character, particularly its strength (count) and condition. It is generally held that grazing sheep on improved pasture markedly strengthens wool, and also increases the amount of condition carried, thus lessening its clean scoured yield, and lowering its value. It was also necessary to see whether repeated (10) monthly drenchings with carbon tetrachloride had had any harmful effect on the fleece, it having been maintained in some instances that such drenching leads to harshness of the fleece.

Count.—The percentages of fleeces classed as from 56's to super 60's in each lot are given below. As set out, 58/60's and 60's are grouped together, as are 60+ and 64, of the latter of which very few occurred.

Lot.	% 56's or less.	% 58.	% 58/60 and 60.	Super. 60 and 64.
1	2	10	57	31
2	..	27	56	17
3	7	20	53	20
4	2	21	58	19
5	4	27	54	15

It is seen that, in each lot, the bulk of fleeces fell in the 58/60, 60's group. In Lot 1 there was a higher percentage of super 60 and 64's, while in the improved pasture lots there was a correspondingly higher proportion of 58's. There was, however, very much less difference in count in the improved compared with unimproved lots than is popularly supposed to occur. It has to be remembered, moreover, that a well and evenly grown 58's wool may have a higher spinning value than a poorly grown 60's, and this point must also be considered in evaluating the effects of improved pastures on wool character.

Staple Length.—Considerable difference in staple length was found when Lot 1 was compared with any of the improved pasture lots. In Lot 1, the bulk of the fleeces were 3 inches to $3\frac{1}{2}$ inches in length, while in all improved pasture groups the majority of fleeces were of 4-inch length or over.

Estimated Clean Scoured Yield.—Clean scoured yield was estimated by a skilled wool classer, after careful examination of each fleece. Contrary to popular opinion, there were considered to be at least as many high-yielding fleeces in each improved pasture lot as on the unimproved lot. The majority of fleeces in all lots fall within a group estimated to yield from 57 to 58 per cent. of scoured wool, and actually in each of Lots 2, 3, 4, and 5 there was a slightly greater proportion of higher yielding wool (59 to 60 per cent. or over) than there was in Lot 1.

Influence of Repeated Drenching.—There was no evidence that repeated drenching with carbon tetrachloride had in any way affected wool character adversely. The wool in Lots 3 and 5 was as clean, bright, and attractive to handle as that of Lots 2 and 4.

4. Parasitic Infestation found on Post-mortem Examination at the End of the Trial.

From faecal cultures, it was found that some degree of infestation with *H. contortus* existed in all groups. It was evident, therefore, that monthly drenching in Lots 3 and 5 had failed to eradicate this species, even though in Lot 5 rotation over pastures rested for three months between successive stockings had been practised. As has been mentioned, several animals in Lots 1, 2, 3, and 4 were killed and examined *post-mortem*. Only very light mixed infestations were found in any animal on improved pasture (Lots 2, 3, and 4), but in sheep from Lot 1, up to 800 adult *H. contortus* were found.

5. Conclusion.

Under conditions met with in this trial, any increased risk of parasitic infestation on heavily stocked improved pastures is more than compensated for by the improved health of sheep, as shown by greatly increased wool and mutton production. Nevertheless, anthelmintic treatment of sheep on improved pasture may lead to material increases in wool production, when compared with similar groups not so treated. While the influence of pasture on wool character leads to a slight lowering in count, it does not necessarily lead to the production of wool having a lower estimated clean scoured yield.

per
grain

The Physiological Relations between Tillers of a Wheat Plant.

By *H. Fairfield Smith, B.Sc., M.S.A.**

The primary object of the plant breeder, and the economic incentive behind the plant geneticist's investigations is the production of better yielding varieties of plants. In the course of most plant breeding investigations, it is thus necessary to measure yield with as much accuracy as possible. In so far as the Council's genetical studies of wheat are concerned, it was necessary to determine whether the whole plant or a tiller should be regarded as the unit on which to base investigations. Work to determine that point has now been carried out, and is discussed in the report that follows. It indicates that tillers are not completely independent units, and that it is necessary to deal with the whole plant when considering the yield of wheat.—Ed.

Summary.

Translocation between culms of a wheat plant after the flowering period is possible, but is probably unimportant in the normal plant. Evidence for this statement was obtained by restricting the photosynthetic ability of some culms by defoliating them and darkening their stems. If the attached tillers had their ears cut off, they contributed to the production of grain in the defoliated culms; but if they had ears of their own to fill, then their contribution to a defoliated companion was not appreciable. (Sections 1 and 2.)

Water from the roots is distributed evenly between all tillers of a wheat plant irrespective of individual tillers to which roots are directly attached. (Section 3.)

Excision of side tillers (including some ear-bearing tillers) increased the weight of grains on main culms by 5 per cent. The interpretation is, however, debatable, and it cannot be taken to prove that side tillers are harmful. (Section 4.)

Leaf blades, stem, and ear of a culm each contribute about equally to the dry matter in the grain. (Section 1.)

Engledow and Wadham, in their investigation of yield in barley (6), surmised from more or less circumstantial evidence that tillers may be independent units after the early stages. Dungan (5) has shown that, in the maize plant, suckers can contribute to the nourishment of the main stem when the latter has been stripped of its leaves. The experiments reported in this paper were undertaken to obtain, for wheat, more direct evidence than has yet been available on the possibility of inter-tiller translocation during the later stages of growth. They formed part of an investigation on methods for the analysis of yield in wheat. They indicate that tillers are not completely independent units, and that the plant should be regarded as an individual entity.

1. Experiments of 1930.

The experiment consisted of observing the effect on yield of interfering with the photosynthetic ability of some culms†.

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† Engledow and Wadham (6) use the term "tillers" to describe all side shoots from the primary stem. The primary stem is thus not regarded as a tiller. Accepting this usage of the word, the American word "culm" has been used in this paper to describe ear-bearing stems, the primary stem. The two terms thus overlap but the primary stem is not classed as a culm which fail to bear ears are not classed as culms.

Grain of Canimbla, a late freely tillering variety of wheat, was carefully selected by hand and sown by dibbing to a uniform depth. Seeds were placed 4 inches apart in four rows spaced successively 1 foot, 3 feet, and 1 foot apart. There were thus two pairs of rows with pathways on both sides of each pair. Each plant had between 15 and 33 culms. Near flowering time, five groups of eight healthy neighbouring plants were selected. The eight plants of each group were numbered at random, and treated according to the number thus assigned. Three extra treatments (given in the last column of Table I.) were applied to only one plant each. Flowering of the main ears began on 9th November, and the operations were performed from 10th to 12th November.

After harvest, a few ears which had been damaged by birds, and small ears having less than 13 fertile spikelets were discarded. The remaining ears varied in size from 13 to 26 fertile spikelets per ear, and every plant had ears well distributed over this range. Measurements indicated in the Appendix were recorded for each culm separately.

Ability to produce carbohydrates was reduced both by defoliation (cutting off leaf blades) and by excluding light from the stems. The latter effect was obtained by using tubes made of brown paper. Three layers of paper were used to obtain an almost opaque cover, but it was not quite opaque in full sunlight. The covers were subject to two other defects in that the upper edges of the tubes were only loosely fastened with paper clips to allow unrestricted growth of the culms so some light would be admitted at this point, and each tube enclosed several culms of different heights, so that some had a considerable length of stem above the enclosing tube, while others had the ear still partially below the rim.

Attention was concentrated on defoliated and darkened culms, but other treatments were also included. Treatments fall into three main groups:—

- A.—Plants in which all culms were similarly treated. (These plants serve as controls for groups B and C).
- B.—About one-fifth of the number of culms of a plant were defoliated, or defoliated and darkened; the other culms were untouched.
- C.—Similar to B, but the ears were cut off the other culms.

The various treatments and the relation between them is indicated in Table I.

In order to reduce the error of estimates of yield per ear, use was made of the regression of yield characters on the number of fertile spikelets, a character determined before, and unaffected by, treatments (*vide* Appendix). Twenty fertile spikelets were selected as a suitable size of ear near the centre of the range to be used as a standard size. Weight per grain, and number of grains per ear, were estimated for an ear of this size for each treatment. Differences in numbers of grains per ear between groups A, B, and C were negligible. Weights per grain are given in Table I.

In Table I. are also shown the differences in weight per grain between controls, in which the normal yield has been, presumably, reduced equally in all culms, and corresponding culms in other plants which may show the benefit of any possible translocation from attached tillers. Although considered individually only one of these differences approaches significance, the consistency over all groups suggest that a conclusion may be drawn with some confidence. It is at least strongly suggested that if a tiller has no ear of its own to fill, then material may be translocated from it to attached culms whose productive powers have been decreased. But if a tiller has an ear of its own, it fails to supply any appreciable quantity of foodstuffs to needy neighbours. Even under the former condition translocation, although possible, appears to be extremely inefficient. Earless culms were over three times as numerous as the defoliated and darkened culms, but they enabled these to regain only less than half of the reduction in grain size caused by the treatment.

TABLE I.—AVERAGE WEIGHT (MG.M.) PER GRAIN PER STANDARD EAR^o (HAVING 20 FERTILE SPIKELETS) FOR GROUPS OF CULMS AS INDICATED.

	Replicated five times.				Only one plant each.
	Normal.	Defoliated, stems light.	Leaves and stems darkened.	Defoliated, stems darkened.	Leaves, stems and ears all darkened.
A—All culms of a plant treated as indicated in the upper margin, (serving as controls for groups B and C)	40.1	30.2	24.1	20.6	10.2
B—Four to six culms of a plant treated as indicated, the other culms left normal	*35.0	†30.0	..	‡21.7	§9.2
C—Four to six culms of a plant treated as indicated, the ears cut off other culms . . . . .	..	†36.5	..	‡20.4	§14.2
Difference, B—A ..	-5.1±3.3	-0.2	..	1.1±3.2	-1.0
„ C—A ..	..	6.3	..	11.8±3.2	4.0

* Estimated for the mean of all normal tillers in group B—two plants in each block.

† Estimated from two or three culms in one plant of each block. The same plant had also two or three culms with stems darkened which contribute to data in column 4.

‡ Estimated from four-six culms in one plant in each block, plus two-three culms in a second plant as noted in the preceding footnote.

§ Estimated from three culms.

|| For this difference $t = 2.8$, $n = 8$, $P = .03$. Other differences between controls and groups B and C are not significant.

GENERAL NOTE.—All plants have a total of between 15 and 33 culms.

TABLE II.—WEIGHTS OF GRAIN PER STANDARD EAR FOR PLANTS OF GROUP A.

1. Normal	1.90 grm.
2. Defoliated	1.35 „
3. With leaves, leaves and stems darkened .. .. .	.99 „
4. Defoliated, stems darkened .. .. .	.79 „
5. Leaves, stems and ears all darkened .. .. .	.34 „
(Standard error of a difference	
.28)	

For the plants of group A the total grain weights per ear of 20 fertile spikelets are given in Table II. They indicate that the ear (glumes, awns, &c.), the stem, and the leaf blades each contributed about one-third of the normal weight of the grain. In view of the defects of the covers used and since the grain may be expected to extract the maximum possible amount of carbohydrate from the glumes, &c., when other sources of supply—leaves and stems—are put out of action, treatment 4 ought to over-estimate the amount normally contributed by the ear. It appears, therefore, that under ordinary conditions the ear probably contributes less than 40 per cent. ($0.79/1.90 = 41\%$) of the material in the grain. It may be of interest to compare this with the finding of Boonstra (3) that almost the whole of the carbohydrate in the grain is contributed by the glumes.

2. Experiments of 1931.

Similar experiments, but using only abscission operations, were conducted in 1931. Canimbla was again used. The plan of seeding was similar to that of 1930, except that only 6 inches separated a pair of rows. Five adjacent plants were taken to form a block. To each plant one of five operations was assigned at random. There were nine blocks. Measurements of yield were taken on only the two largest culms of each plant which were marked with wool when operations were performed. In addition to the more usual measurements of yield, the weight of 10 grains, obtained by taking the two basal grains from the five largest spikelets of each ear, was also observed. It was thought that this might be a more accurate measure of grain size than is the average weight per grain usually employed, although there is little difference between the two measures. The correlation between them is $r = .956$ and the ten selected grains were about 16 per cent. heavier than the average of all grains per ear. The weight of the 20 grains thus obtained from each plant was used as the measure of weight per grain per plant.

Owing to the use of only the two largest ears per plant, variation in size of ear was small and correlation between grain weight and number of spikelets was insignificant. Consequently, in this experiment there is no gain obtainable by estimating values for a standard size of ear; simple averages per treatment are equally efficient.

The five treatments used, and the mean weight of 20 grains for each treatment are shown in Table III. From the analysis of variance (Table IV.), it appears that the differences between treatments are not significant. The experiment is nevertheless reported here because such differences as exist agree with the results of 1930.

The effect of cutting off leaves may be estimated from twice as many differences as are available for a comparison between any two single treatments. It may be estimated from treatments 1 and 2 versus 3 and 5. This difference is significant. It is 20.6 ± 8.0 cgms., $t = 2.6$, $n = 39$ (Table IV.), $P < .02 > .01$. The decrease is 22.5 per cent. and it agrees closely with the decrease of 25 per cent. between treatments 1 and 2 in 1930.

A further five pairs of plants had the leaves cut off the two largest culms. As to the remaining tillers, they were cut entirely off one plant of each pair, whereas in the other of each pair they had their ears cut

off. Corresponding ears were compared in pairs by Student's method, with respect to the weight of 10 grains. One ear was damaged leaving 9 pairs. The culms accompanied by earless tillers gave heavier grain than the solitary ones. The difference was 12 cgms., ± 3.2 , $t = 3.8$, $n = 8$, $P = .01$. This therefore corroborates the experiments of 1930 in showing that under special circumstances translocation between tillers and culms is possible.

TABLE III.—TREATMENTS AND GRAIN WEIGHTS FOR 1931 EXPERIMENT.

Treatment.				Mean Weight of 20 Grains (centigrams)	Mean No. of Grains from Two Ears.
Two Largest Culms.		Remaining Tillers.			
Normal	..	Normal	..	94.2	83
Normal	..	Cut off at the base	..	89.2	91
Leaves excised	..	Normal	..	72.9	86
Leaves excised	..	Ears cut off	..	73.8	76
Leaves excised	..	Cut off at the base	..	69.0	84
Standard error		..	..	7.8	6.7

TABLE IV.—ANALYSIS OF VARIANCE FOR 1931 EXPERIMENT.

Due to—				Degrees of Freedom.	Sum of Squares.	Mean Square.	Log _e
Treatment	..	..	..	4	4,419.2	1,104.8	7.007
Blocks	..	..	..	8	2,068.2	258.5	
Remainder	..	..	..	31	19,545.6	630.5	
Blocks + Remainder	..	..	..	39	21,613.8	554.2	6.317
Total	..	..	..	43*	26,033.0		

$$z = .345 \quad P > .05$$

* One plant in Treatment 1 was seriously diseased and had to be discarded. Attributes for this plant were estimated by Allan and Wishart's formula (1). One degree of freedom was thus lost, making the total number 43 in place of 44, which would be expected for 45 plants.

3. Lateral Translocation of Water from Roots.

At the beginning of their flowering period in 1930, some further experiments on translocation from the roots were performed on plants of *Canimbla* growing at 4 x 12-inch spacing. By spraying with water from a hose, the earth was washed away from the roots on one side of six plants. About one-third of the roots of each were then severed by cutting. Waxed paper was inserted below the cut surfaces to prevent development of new roots.

After harvest, it was not possible to identify with certainty all the roots growing from each individual tiller, but the tillers of each plant could be divided into three groups:—(1) those on one side whose roots

had not been touched, (2) those on the other side practically all of whose roots had been cut, and (3) a group in the middle whose status could not be determined with certainty. By a similar method of analysis to that described for the 1930 experiment, it was found that the weights of grain per ear of twenty fertile spikelets were as follow:—

Control	.. .. .	1.93 ± .033 gms.
Experimental plants. Culms with roots remaining		1.47 ± .054 "
" " " " " cut		1.46 ± .073 "

Cutting a third of the roots affected the yield from the whole plant; but culms whose roots had been severed were not affected more than were culms whose roots remained attached. It therefore seems that supplies from the roots may be distributed to any culms of the plant, irrespective of those to which the supplying roots are directly attached.

Richardson and Trumble (8), and Burd (4) have shown that under normal conditions most of the minerals absorbed by barley are taken up during the early stages of growth; Gericke (7) found that to enable wheat to produce its full yield, only water, with perhaps traces of iron and nitrogen, is required during the later stages of growth. For trees, Auchter (2) found that water can be supplied by any root to any part of the plant, but that minerals tend to remain on the same side of the tree as that on which they are absorbed. The above demonstration of lateral distribution from the roots of a wheat plant may therefore be applied only to water. The distribution of mineral nutrients requires separate demonstration.

4. Effect of Removing Side Tillers on the Yield of Main Culms.

Having shown that translocation between culms is possible, can we obtain any evidence as to whether or not side tillers which fail to bear ears may be only parasitic on, or competitors against, the main culms, without service rendered in return? Dungan (5), in reviewing the literature, indicates that removing non-earbearing suckers from maize plants is detrimental to their yield.

A bed which had been sown with Canimbla wheat at 6 x 2-inch spacing was divided into eight plots. Where different treatments were adjacent a 6-inch border was discarded. The plots were arranged and numbered as follows:—

1	2	3	4
5	6	7	8

Plots 1 to 4 were 2 x 4 feet, and plots 5 to 8 were 2 x 2 feet, but records have not been collected for all the plants in each plot. Plots 5 to 8, which were lower than plots 1 to 4 owing to the slope of the ground, were irrigated weekly. Flowering began about 26th October. On 19th October, in plots 2, 3, 5, and 8 tillers were cut off to leave only two main culms. Plants which were not large enough to produce two good size ears had only one culm left. In addition to very small side tillers which were from 1 to 6 in number and which had already withered, there was cut off from each plant from 0 to 5 tillers of a size which would have died later, and 0 to 3 tillers large enough to have formed ears.

After harvest, the weight of 6 grains per ear, 2 basal grains from each of the three largest spikelets, was obtained for two ears per plant (or for some plants as indicated above, one ear). Evidence that the plots were similar and evenly matched before operations were begun is given by the means and standard deviations of the numbers of fertile spikelets per ear. (Table V.) Since there was no correlation between grain weight and number of spikelets, grain weight has been treated as an independent character. Within each plot, the frequency distribution of grain weight was approximately normal between 24 and 36 cgms., but extended below this range more or less erratically down to six cgms. The light grains were due to plants attacked by foot-rot. Since, however, it is difficult to fix a border line between diseased and healthy plants, it is difficult to decide what ones should be discarded, but if all are kept, these light grains seriously upset the values of the means. It was therefore decided to use the modes as the best estimate of grain weight for each plot. Modes were estimated by the formula

$$Mo = x_m - \frac{1}{2} \Delta x + \frac{f_m + 1}{f_{m-1} + f_{m+1}} \Delta x$$

and are shown in Table V. An analysis of variance for a comparison between plots is given in Table VI., whence it appears that the grains from the treated plots are slightly, but significantly, heavier than the grains from the controls.

Analysis of the data was carried further by classifying the treated plants according to the number of excised tillers which might have borne ears. For this purpose, it was deemed permissible—since previous examination had shown that differences between corresponding plots were negligible—to treat all plant records from the four treated plots as a homogeneous sample.

Four rows (no two adjacent) had to be discarded because after harvest the plants could not be connected plant for plant with the field notes. By coincidence, these rows contained the worst of the diseased plants so that the distribution of the remainder was close enough to the normal distribution to permit the use of means. The mean grain weight for untreated plants neglecting all values less than 20 cgms., was calculated to provide a comparable value for the controls. The mean grain weights per 6 grains for each class were as follow:—

(1) Controls (discarding weights per 6 grains less than 20 cgms.) ..	29.38 ± .34 cgms.
(2) Only non-earbearing tillers excised..	30.01 ± .39 „
(3) One earbearing tiller excised ..	30.91 ± .27 „
(4) Two or three earbearing tillers excised	30.97 ± .27 „

Of the differences between treated groups, that between classes (2) and (4) just approaches significance. The difference is $.96 \pm .47$. ($P = .04$).

These results cannot however be accepted as proof that side tillers are harmful to the production of grain on the main culms. A possible explanation of the differences observed is that during the hot days of

summer the root systems of the plants whose culm number had been reduced to two were better able to deal with demands upon them for water. Since it has been shown that water supply is not restricted to tillers from which the supplying roots have grown, and since the extra tillers contributed to the formation of roots before they were taken away, there is no indication that the gain could have been obtained if the plants never had the excised tillers. It seems possible that tillers

TABLE V.—MEAN AND STANDARD DEVIATION OF NUMBER OF FERTILE SPIKELETS PER EAR, AND MODES OF WEIGHTS OF 6 GRAINS PER EAR FOR EACH PLOT.

Plot No.	Number of Fertile Spikelets.		Modal Weight of 6 Grains (centigrams)	No. of Ears Examined
	Mean.	Standard Deviation.		
1	14.4	2.5	30.0	106
2	14.1	2.1	30.8	107
3	14.2	2.4	30.9	99
4	14.3	2.3	29.6	86
5	13.2	2.0	31.0	51
6	13.5	2.1	29.0	61
7	13.6	2.2	28.7	51
8	14.4	2.2	30.9	41

TABLE VI.—ANALYSIS OF VARIANCE FOR THE MODAL VALUES OF GRAIN WEIGHT IN ALL PLOTS.

Due to—		Degrees of Freedom	Sum of Squares	Mean Square.	<i>z.</i>	<i>P.</i>
Between treatments	..	1	4.961	3.904	1.794	< .01
Between blocks*	..	1	.361	1.284	.484	> .05
Remainder	..	5	.687	.315		
Total	..	7	6.009	..	..

* Includes effect (if any) of irrigation.

Mean of treated plots = 30.9 cgms.
 " " control " = 29.3 "
 Difference = 1.6 ± 0.4 .

which die about flowering time, if they have contributed to root growth, may not have lived in vain, but this possibility may not be assumed without further proof. In any case, this form of service will only be applicable when soil water is adequate and when transpiration is great enough to tax the supplying power of the roots; for example under conditions of irrigation or in hot countries when, as in Eastern Australia

in 1931, rainfall during the grain filling period is plentiful. It cannot be expected to apply when soil water is limiting, or where, as in England, evaporation is low.

5. Literature Cited.

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Appendix I.—The Methods of Calculation used in Section I.

Underlying the plan of the 1930 experiment, there lay an intention to compare the yields of the treated and control culms by comparison of the regressions of yield on some stable culm character which was unlikely to be effected by the treatments. A secondary object of the experiment was to test the practicability of using such a method in yield experiments. Since grain weight per ear varies with the size of culm, it is unsatisfactory to compare directly culms of different sizes. A comparison of regressions of grain weight on size of ear is equivalent to comparing average grain weights for corresponding ear sizes without the labour of matching ear for ear. Characters considered as possible to indicate culms of corresponding size were, number of fertile spikelets, number of sterile spikelets, total number of spikelets, length of ear, weight of chaff plus rachis, weight of straw, and length of straw. Numbers of spikelets are probably least likely to be affected by the treatments, and it was found that number of fertile spikelets was more closely correlated with grain yield than any other of the characters enumerated. The following correlations to this character were obtained for 70 culms from four normal plants.

Between weight of grain per ear and number of	
fertile spikelets	$r = .91$

Between number of grains per ear and number of fertile spikelets	= .89
Between average weight per grain per ear and num- ber of fertile spikelets	= .61

For analytical yield studies, it seems advisable to consider separately the components of yield, number of grains, and weight per grain. In the following discussion, only weight per grain is considered. Number of grains was similarly examined.

Let number of fertile spikelets be designated F , and let weight per grain be g .

TABLE VII.—ANALYSIS OF VARIANCE FOR FOUR NORMAL PLANTS.

Due to—	Degrees of Freedom.	Sum of Squares.	Mean Square.
Variance about regression of g on F within single plants	51	179.8	3.53
Variance between values of g for $F = 20$ in each plant	3	97.2	32.4

TABLE VIII.—ANALYSIS OF VARIANCE FOR FIVE PLANTS HAVING ALL
CULMS DEFOLIATED AND STEMS DARKENED.

Due to (see Table I)—	Degrees of Freedom.	Sum of Squares.	Mean Square.
Within plants	62	214.9	3.46
Between plants	4	104.1	26.0

Preliminary observation of normal plants had suggested that the relation between g and F per culm might be the same for all plants in a small plot, but critical statistical examination—Tables VII. and VIII.—showed that this was not the case. A sample formed of several tillers from several plants was not homogeneous. Therefore to obtain valid estimates of error for comparisons between plants, it was necessary to calculate a separate regression for each plant and thence obtain a single measure per treatment per block. Since different treatments had considerably different numbers of culms from which records were obtained

(*vide* Table I.), an average error for different treatments could only be obtained for treatments with similar numbers of culms. Consequently, degrees of freedom available for estimating errors were few. The procedure is tedious, and where differences were obviously insignificant—owing either to the smallness of a difference or to the small number of observations concerned—or where an estimate of error was unimportant, the grain weight was estimated from bulked data in which each plant had equal weight.

In view of the differences between plants indicated by Tables VII. and VIII., the suggested method, using regressions, is not convenient for dealing with a few large plants as in the present case. The experiment of 1931 indicates that if a large number of plants with only a few ears from each be used, then ears may be readily selected which are so similar that the correlation of characters within them is not worth considering for the purpose of increasing the accuracy of the means.

Explanation of “analysis of variance,” and of the statistics z , t , n , and P may be found in “Statistical Methods for Research Workers” by R. A. Fisher.

A Note on Some Aspects of Anti-Bacterial Immunity.

By L. B. Bull, D.V.Sc.

For some time past, the Council's Division of Animal Health has been giving a considerable amount of attention to determinations of the precise causes (generally a determination of the species of bacillus concerned) of a number of previously obscure diseases of Australian livestock. The recent work on black disease of sheep, braxy-like disease in Western Australia, pulpy kidney, &c., are instances of this work. Generally, once the cause of a disease is known, a means of control can be suggested. At times, however, such control methods, and methods developed for other diseases the causes of which have long been known, are not particularly simple or economic. Nevertheless, the rather rapid advances in the field of immunology that have been made during recent years are full of promise in connexion with the development of disease control methods in general. Dr. L. B. Bull, Director of the Government Laboratory of Bacteriology and Pathology, Adelaide Hospital, has recently prepared a brief statement dealing with various aspects of such immunological work in connexion with a matter which he has been discussing with the Chief of the Council's Division of Animal Health, Dr. J. A. Gilruth. That statement, however, is of general interest, and Dr. Bull has now kindly agreed to having it printed below.—Ed.

In this note, we will not consider the filterable viruses nor the immunity produced following recovery from their invasion of the animal body.

Pasteur was the first to employ bacteria for the purpose of producing resistance to natural infection. He introduced the method of employing attenuated cultures for this purpose. The basis of the procedure was the belief that any particular bacterium growing in the animal body exhausts the pabulum for that particular organism, and so the body is protected against further invasion. He therefore used live, although attenuated, cultures of the organisms, and injected them under the skin of the animal.

Although very great success was obtained by Pasteur and others following his methods, the employment of living cultures has usually given rise to some loss of life, and in some instances to very great loss of life. The fixity of the attenuation could not always be relied upon, and if attenuation were carried too far the resistance produced might be too slight to be effective against natural infection. Further, the use of living cultures is associated with a risk of disseminating infection. Although the methods have been employed very largely for the protection of the domesticated animals, they have not been used to any extent to protect human beings, and there has been an increasing tendency to depart from the use of living cultures in veterinary work. At the same time, it is generally recognized that the living antigen is superior in most instances. There is an exception to this, however, in the case of infections due to bacteria producing a diffusible toxin. Many bacteria which were unsuspected as toxin-producers have, of recent years, been shown to produce powerful toxins, and these can also be produced under artificial conditions if proper methods are used.

Immunity to infection by these toxin-producers has been shown to be almost, if not entirely, an antitoxic immunity, and very much better results are to be obtained by artificial inoculation with toxin or modified toxin than by attenuated cultures of these organisms. This fact is best illustrated in the infections due to many of the anaerobic bacilli.

The advance along these lines is very important, and it illustrates that we can, by artificial means, produce results that are greatly superior to those obtained under natural conditions. It is held by many that if immunity does not result from natural infection then we are not justified in hoping to produce an immunity by artificial means. The degree of immunity that can be produced artificially by the use of modified toxins is much greater than occurs under natural conditions. This result has been rendered possible by a more thorough understanding of the factors responsible for the production of disease and the antigenic make-up of bacteria and their products.

Nowadays, we believe that Pasteur was wrong in holding that exhaustion of a special pabulum in the animal body was necessary for the production of immunity. From this point of view, therefore, it is no longer necessary to employ living bacteria in protective inoculations. Further, we now know that attenuation of virulence of bacteria is accompanied by very definite changes in the make-up of these micro-organisms, the change usually being the loss of something which is of importance antigenically. Therefore, according to our present knowledge, the use of living attenuated cultures for the production of immunity is possibly not the best method. With increasing knowledge of the nature of bacteria and their products as stimulators of anti-body formation, we can reasonably hope to produce more efficient and safer vaccines than have been used in the past. It seems possible also that we may be able to devise methods that will produce resistance in the animal body to bacterial diseases which, under natural conditions, do not appear to give rise to any very definite degree of resistance. It is possible that such methods might involve injections at intervals over a period of years if the resistance is to be prolonged, but the disadvantage would not be very great if the procedure were perfectly safe and easy.

Of recent years, studies of bacterial variation as well as studies of the chemical structure and the immunizing properties of bacterial antigens have explained in part, if not fully, many former difficulties and failures, and have placed the problem of bacterial immunity on a more secure basis.

Bacterial Variation.

The views on bacterial variation of earlier workers were largely based on the study of impure cultures. Of recent years, it has been clearly demonstrated that colony formation can be correlated with variation in other properties, many of which are of fundamental importance to the practical problems of immunity. Arkwright has shown that in plating cultures of laboratory strains of many bacteria two types of colonies may be found. One type is smooth and more translucent, whilst the other has a rough, matt surface, and is more opaque. He designated these varieties as "smooth" (S) and "rough" (R), respectively. The smooth colonies are associated with virulence, and the rough with loss of virulence. There are also other characteristics associated with these colonial appearances, such as that of spontaneous clumping in salt

solution and, sometimes, loss of motility by the rough cultures. Further, serological tests with monovalent sera show that the two types are antigenically specific, at least in the higher dilutions. These observations have been confirmed by many workers, and on many different species of bacteria.

It may be said that there is a general tendency for bacteria cultivated under artificial conditions to vary from smooth to rough, the variation being accompanied by loss of virulence and some antigenic constituents.

Associated with these studies are those of Weil and Felix, who showed that motile bacteria possessed two antigenic constituents responsible for the production of agglutinins in the inoculated or infected animals. These two constituents have been called H and O, respectively, the H being associated with the flagella of the bacterium, and the O with the body (somatic).

A further aspect of this subject was developed by Andrews, who showed that H agglutinins may be either "group" or "specific".

The conception has grown up of an antigenic "spectrum" within certain pathogenic species of bacteria, with groups or strains arranged in bands, as it were, which in some cases are sharply marked off, but in others shade into each other.

These observations are of fundamental importance, and help to illustrate the complicated nature of the bacterial organism, particularly with regard to its antigenic make-up.

Side by side with these studies are others which have been made by a chemical analysis of the bacterial cells, and the two taken together give us a new conception, and a new method of approach to the practical problems of immunity.

Chemical and Physico-chemical Studies.

It is only since more thorough knowledge of bacteria themselves, their physical and chemical structures, is being built up that we can see the possibility of much greater development in the application of this knowledge to the problems of immunity.

For many years, specificity in immunity reactions was considered to be wholly bound up with the structure of the protein. Landsteiner and his associates were responsible for demonstrating that the specificity of a large colloidal molecule may be determined by a comparatively small reactive group in that molecule, and he called this reactive group a haptene or partial antigen. This work has been carried on with protein substances, many of them very complex, to which have been linked more simple reactive substances, the most interesting, from our point of view, being some of the more simple carbohydrates. It has been shown that the specificity of these linked compounds is determined entirely by the chemical (and physical) properties of the carbohydrate or other substance linked with the protein. Two proteins with entirely distinct immunological characteristics can be made to give identical immunological reactions if linked in the same way with the same carbohydrate.

A considerable amount of work has been done on the chemical constitution of bacteria, but much of it has led to little knowledge of fundamental importance. Of recent years, however, results of the greatest importance have been obtained. Avery and Heidelberger, working with the pneumococcus, were able to show that a very important

product, apparently associated with the capsule and diffusible into the medium, was a carbohydrate substance, a polysaccharide very similar to the vegetable gums. Later, they showed that this substance determined the specificity of the organism, and that it differed chemically and immunologically in the three main types of pneumococci.

Since then, a mass of work is accumulating on similar lines, and many species of bacteria have been examined, and in each case it has been determined that the specificity of the organism resides very largely in the polysaccharide which is loosely bound to the protein of the organism.

This chemical work links up with the more purely bacteriological work of Arkwright and others. It has been shown that the variation from smooth to rough is associated with a loss of the specific polysaccharide, and that the O agglutinin is likewise closely associated with the same substance.

The serum reactions which we have associated in the past with anti-bacterial immunity are shown now to be not necessarily proportional to the degree of resistance of the animal. Agglutinins may be produced quite easily by the inoculation of bacteria which have undergone rough variation, or have lost their virulence, and yet the animals possess no specific resistance to infection. Bacteria are shown to be very complex organisms, and it is necessary to know how they can be handled without loss of, or damage to, the specific substances before we can use killed suspensions for the stimulation of resistance to invasion by virulent members of the same species.

It is known that physical disruption of the bacterial cell may completely destroy the specificity of the antigenic substances present. Much of the handling that bacterial suspensions have been subjected to in the past can be calculated to destroy this specificity completely, whereas heat, which was for so long considered to be destructive of specificity, is now known not to be so, at least in the majority of cases.

General.

In this brief outline, an attempt has been made to indicate how this newer knowledge has opened up very promising fields for investigation. A vast amount of work still remains to be done and, although the way has been indicated, each species of bacteria offers its own special problem.

It is extremely difficult for the animal body to deal with some of the more resistant types of bacteria. The reactions of the animal body to the presence of a foreign protein or antigenic complex is probably fundamentally the same in all cases. Bacteria are, however, different from other foreign proteins in being particulate. Their antigenic specificity is destroyed by proteolytic enzymes, by physical disruption, and other changes. Being particulate, and not in soluble form, they do not constitute ideal antigens.

Future work will have to be directed towards an attempt to prepare bacterial antigens in a more suitable form while preserving their specificity. In this work the chemist will play a very important part, and each step will have to be controlled by crucial tests for specificity as understood in the light of the fundamental work briefly indicated above.

The Use of Creosote and other Tar Oils as Motor Fuels.

By L. J. Rogers, M.Sc., B.E.

Mr. Rogers was one of the first Australian graduates to receive a research studentship from the Science and Industry Endowment Fund. He left Australia in 1926, and after spending his studentship at the British Fuel Research Board's Station at Greenwich, he served for a period as a member of the staff of the Station. Recently, he returned to Australia in order to assist generally in liquid fuel problems. A short time ago he was asked by the Vice-President of the Executive Council (Senator the Hon. A. J. McLachlan) to furnish a report on the Australian possibilities of the use of creosote and other tar oils in motor engines. The article that follows is based on that report.—Ed.

1. Introduction.

The present world-wide depression in the market for tar products has inspired a number of investigations into alternative methods of utilization. Some prominence has been given recently to researches carried out in Ireland and England on the use of creosote as a fuel for internal combustion engines. To a country like Australia, situated very unfavorably as regards supplies of petrol, and possessing what may be considered unlimited reserves of high class coal, the possibilities revealed in these investigations appear very attractive at first sight. Creosote, however, is produced in such small quantities that it can never be more than a by-product of other industries, and the supply will always be limited by the demand for gas and coke. Nevertheless, at present, it is difficult to find a market for Australia's production, and a new use for it, as well as for other tar oils, would be welcomed by local distillers. In the following report, a brief survey is made of technical considerations in the application of creosote as a fuel for motor vehicles, and the economic aspect of the problem as it affects Australia generally.

2. Theoretical Considerations.

The nature of the fuel used in motor car engines is prescribed mainly by the conditions under which the vehicle is to operate. In the case of a private car, convenience demands that the engine shall be able to start directly upon the fuel in all weathers. The driver cannot be expected to waste his time and soil his hands in priming the cylinders or heating the induction pipe, so that the only permissible expedients for assisting ignition are the flooding of the carburettor and the use of a choke. On the other hand, a commercial vehicle may use a cheaper and less volatile spirit by resorting to priming, if necessary, when starting from cold. The petrol used by the London General Omnibus Company, for instance, consists of No. 2 spirit to which is added 30 per cent. of duty-free (heavy) fuel.

For satisfactory operation upon heavy fuels, it is necessary to heat the induction system by contact with the exhaust manifold. The minimum temperature of preheat is prescribed by the necessity for evaporating sufficient fuel to form an explosive mixture in the combustion chamber. The optimum temperature, however, is determined by

the tendency of the fuel to condense in the induction pipe. If condensation is allowed to occur, the response to the throttle will be sluggish, and the distribution of the fuel between the different cylinders of the engine will be uneven. Loss of power and efficiency will ensue, and the performance of the engine will be impaired generally. A certain amount of preheating of the fuel and air is arranged for in the average car, to enable a cheaper fuel to be used than would otherwise be possible. But the temperature to which the air must be heated for consuming kerosene is much higher than for normal petrol. The heating of the charge in this way reduces the weight of fuel and air which is drawn into the cylinder at each suction stroke. The use of heavy fuels therefore entails a loss of power in the engine which may be quite considerable. For this reason, racing engines and aeroplane engines do not have heated induction systems, and are obliged to use volatile spirits for satisfactory performance.

In the case of petroleum oils, it is found that the tendency to detonate increases with the density of the fuel. Engines designed to use heavy fuels—tractors, for instance—therefore have low compression ratios. This involves a further loss of power, and a pronounced reduction in efficiency. In one particular case, it has been found that the power output of a certain petrol engine was reduced altogether by 17 per cent. when adapted to burn kerosene.

Low volatile fuels condense readily on the walls of the engine cylinder. The low temperature of the liquid film on the cylinder walls and its comparatively poor access to oxygen result in incomplete combustion and the formation of carbon. Unburnt fuel is scraped by the piston rings into the sump, where it contaminates the lubricating oil. The use of heavy fuels therefore necessitates more frequent draining of the sump and renewal of the oil. To minimize these disabilities, it is desirable to maintain the temperature of the cooling water, and thereby that of the cylinders, as high as is possible without risk of local overheating. The formation of carbon on hot spots, such as valves and piston heads, is favoured by the fact that heavy petroleum hydrocarbons are more easily decomposed by heat than are lighter fractions. The use of kerosene therefore involves more frequent overhauls, with increased costs for maintenance and loss of services while the vehicle is under repair.

The advantages and disadvantages of using a heavy fuel in a motor vehicle may be summed up as follows:—

For—

Reduced cost of fuel per gallon.

Higher mileage per gallon in virtue of its greater calorific value per unit volume, and in spite of its lower efficiency.

Lower inflammability.

Of these three items only the first is of great importance.

Against—

Lower power output from a given engine, or, alternatively, the extra cost of a larger engine for developing the same power.

Higher maintenance costs.

More frequent renewals of lubricating oil.

The utilization of tar oils instead of heavy petroleum is favoured by the high anti-detonating value of aromatic hydrocarbons as compared with paraffins and naphthenes. Creosote can be used in a car

engine with no reduction in compression ratio and consequent loss of efficiency. Indeed, it is possible to use a higher compression than is normal in a petrol engine. Owing to the stability of aromatic hydrocarbons, moreover, it might be expected that the deposition of carbon in the cylinder head would be reduced. This expectation may not be fulfilled in practice, however, for benzol, presumably on account of its slow burning characteristics, is found to make at least as much carbon as aliphatic petrols. Creosote suffers from the disadvantages of a lower calorific value, a propensity for forming gums by oxidation and polymerization, and possibly a tendency for depositing pitchy material in contact with paraffin base lubricating oil.

3. Experience in Belfast and England.

The first attempts to employ creosote as a motor fuel on a large scale were made in Belfast in March, 1929. Technical difficulties have been so far overcome that a number of buses operated by the Belfast Omnibus Company have been using the fuel for nearly two years. The application of creosote is now reported to be spreading to private cars.

The alterations and additions to the equipment of the Belfast buses, for adapting the engine to the new fuel are as follows:—

1. A new induction system surrounded by, and cast integrally with, the exhaust manifold. This intake has been patented by the Solex Company.
2. A second carburettor—of the horizontal Solex type—for use when running on creosote.
3. A separate tank and feed line for the creosote fuel.
4. A second accelerator pedal, with automatic arrangements for closing the petrol throttle when the creosote carburettor is in action, and for allowing a limited quantity of petrol to pass when the creosote throttle is closed.

The engine is started with petrol in the usual way, and kept running on this fuel until the exhaust manifold is hot enough to vaporize the creosote. The second accelerator is then used, automatically shutting off the supply of petrol. When running idle, the creosote throttle is closed, and petrol automatically substituted for the heavier fuel. After temporary stoppages for picking up and setting down passengers, the bus is driven off directly on creosote.

The fuel used at Belfast is prepared from high temperature tar produced in Glover-West vertical retorts. The crude tar is distilled, and the fraction boiling between about 180 deg. C. and 300 deg. C. is washed and mixed with 10 per cent. of water-white solvent naphtha to keep naphthalene in solution. The motor fuel prepared in this way has a specific gravity of 0.951, a tar acid content of 15 per cent., and a closed flash point of 129 deg. F. It is understood that the fuel may be purchased for 6d. per gallon.

The Belfast authorities have not fitted their buses with a high compression head in preference to the normal cylinder head. Their saving in fuel, therefore, cannot exceed that indicated by the respective calorific values of creosote and petrol on a volumetric basis, viz., about 8 per cent. With the carburettor correctly adjusted in each case, there is no reason why creosote should be more efficient than petrol. Indeed the

difference, if any, should be in favour of the more volatile fuel. The "pull" of the engine has been described as very satisfactory. This is probably due to the fact that the engine can be run at low speeds and full throttle without detonating. Changing down on hills may therefore be avoided in some cases, but there can be no doubt that a dynamometer test would indicate a deficiency in power.

One of the greatest objections to the use of heavy fuels in internal combustion engines for vehicles is the smoke and smell discharged from the exhaust. When the engine is rather cold, as, for example, after a short stoppage, combustion is imperfect, and fumes appear in the exhaust gases. This has proved an objection to the use of Diesel engines in buses, and the same trouble apparently is experienced with creosote. The smell of creosote is not as objectionable as that of burnt oil, being on the contrary rather wholesome. It is probable that this trouble will be overcome and that satisfactory operation will be made possible in city streets.

Investigations have also been carried out by the Manchester Corporation, the Gas Light and Coke Company, and the London General Omnibus Co. The most interesting fact arising out of the Gas Light and Coke Company's experiments is the possibility of using a heavy creosote prepared by distilling to pitch. The fuel used consists of creosote boiling between 180 deg. C. and 350 deg. C., with the addition of 20 per cent. of benzol. Horizontal retort tar is employed in this instance, so that the proportion of solvent required is increased.

The original Belfast arrangements were modified by the Gas Light and Coke Company by constructing a manifold of its own design, and by using a single carburettor with a change-over switch in the fuel line. To take advantage of the opportunity for increased fuel economy, and to compensate to some extent for the loss of power due to lower volumetric efficiency, the compression ratio of the engine has been increased from 5:1 to 6.6:1.

For satisfactory performance on heavy creosote, the temperature of the cooling water needs to be maintained above 80 deg. C., and the temperature of the induction pipe above 230 deg. C. When this temperature falls below the figure mentioned, fumes appear in the exhaust, and the response to the throttle is sluggish. With the engine idling, the temperature falls to 230 deg. C. in half an hour, and the throttle must then be opened slowly until the induction system is hot once again. If the temperature falls below 230 deg. C., petrol must be used for warming up. The time required for heating up from cold is about five minutes.

The secret of satisfactory preheating of the fuel and air appears to consist in having a heavy manifold with a substantial heat capacity. The induction pipe should be designed to prevent direct impingement of the fuel on the exhaust manifold, or local overheating will lead to the formation of pitch.

4. Sources of Supply.

Creosote suitable for use as a motor fuel may be prepared from coke-oven tar, horizontal-retort tar, or vertical-retort tar. The main product of each of these tars is a material for road dressing, which contains about 72 per cent. of pitch and 28 per cent. of oils. The presence of the lighter oil is required to

keep the product sufficiently fluid. In England the pitch contents of the three tars mentioned are respectively 70 per cent., 65 per cent., and 55 per cent. The mere removal of water and benzol from coke-oven tar produces a satisfactory road material, so that no creosote is available for other purposes. In concentrating the pitch content of horizontal retort tar from 65 per cent. to 72 per cent., very little creosote is prepared as a by-product. In the distillation of vertical retort tar, however, the residue of creosote would amount to approximately 20 per cent., or 2.7 gallons per ton of coal carbonized under English conditions.

The demand for road tar in England is rather slack at present, but in normal times the market would probably absorb all the road tar available. On the assumption that crude tar is distilled for road binders alone, the annual production of creosote in England would be approximately as follows:—

	Coke Ovens.	Horizontal Retorts.	Vertical Retorts
Coal carbonised, tons ..	17,300,000	8,000,000	10,000,000
Creosote available, gallons ..	..	5,000,000	27,000,000

The production of pitch for briquetting purposes by further distillation of tar would make available about 25 extra gallons of creosote oil for every 100 gallons of tar so treated. The normal production of pitch in the United Kingdom is about 500,000 tons annually. At present the quantity is reduced, but in more settled times the extra amount of tar oils prepared by distillation to pitch may be taken as approximately 38,000,000 gallons. The total supply is therefore about 70,000,000 gallons annually. Of this quantity, the greater part is required for wood preservatives, disinfectants, exports, &c., but a certain amount is at present being burnt as a fuel oil, either as creosote itself or as a constituent of crude tar. The quantity of tar oils which could be prepared for use in motor vehicles without encroaching upon other markets would therefore be only a fraction of 70,000,000 gallons. In view of the fact that England imports 1,000,000,000 gallons of petrol annually, and that the London General Omnibus Company alone uses 35,000,000 gallons, the supply of creosote is seen to be almost insignificant.

In Australia, the pitch contents of coke-oven, horizontal-retort, and vertical-retort tars are respectively 65 per cent., 58 per cent., and 48 per cent. A good road material may be prepared from local coke-oven tar merely by distilling off the water and benzol contained in it. Only 50,000 tons of coal tar per annum are carbonized in horizontal retorts, and then only in small works which do not distil their tar. The consumption of coal in vertical retorts is 1,000,000 tons per annum, yielding, on the average, 22 gallons of tar per ton. The creosote potentially available by distillation for road tar alone is therefore approximately 6,000,000 gallons per annum. In Australia, there is no market for pitch for briquettes, so that the supply of tar oils could not be increased by further distillation for this purpose.

It is not possible, by distillation alone, to prepare a first-class road binder from tar made in vertical retorts from Australian coal. Difficulty is experienced, therefore, in selling road tar in competition with bitumen. Consequently, large quantities of crude tar, amounting to about half the production, are being burned under boilers and stills for want of a more profitable market. If a demand were to arise for creosote motor fuel, this tar could be distilled to a soft pitch for the production of creosote, leaving a residue which might still be used as a boiler fuel, or which alternatively could be returned to the retorts for gas making. It is difficult to estimate the amount of oil which might be prepared from crude tar which at present is being used as a fuel oil, but the quantity would be of the order of 4,000,000 gallons per annum. Further supplies could be secured only by offering prices in excess of the present market rates, and in normal times the quantity available would be considerably less. The value of creosote at Australian gas works is approximately 6d. per gallon, so that a mixture containing 10 per cent. of benzol could probably be delivered in bulk to large consumers for about 9d. per gallon. It may be found, however, that the addition of a solvent to Australian creosote is unnecessary.

The amount of creosote potentially available for consumption as a motor fuel is small compared with Australia's total requirements of about 200,000,000 gallons of such fuel per annum. The utilization of creosote, therefore, is not a question of national importance. To gas works, however, and to transport companies also, the possibility of operating motor vehicles on tar oil fuels should be of considerable interest.

5. Markets for Motor Fuel prepared from Tar.

Owing to the limited and localized supply, the use of creosote must be restricted to the various metropolitan areas. The market for the fuel, moreover, will be restricted to concerns operating fleets of vehicles under expert supervision and with frequent inspections for repairs and renewals. In Australia, bus companies do not appear to be organized on the large scale which is common in England and America. It should be possible, however, to find a market for creosote with transport companies, business firms, and railway departments, if the fuel can be offered at an attractive price. Creosote as a motor fuel can only displace second grade spirit, sold at 1s. 9d. or 1s. 10d. per gallon, resulting in a possible saving of 60 per cent. in fuel costs. Under different conditions, the cost of petrol amounts to between 15 per cent. and 40 per cent. of the total running expenses of a vehicle. For the present purpose, a round figure of 25 per cent. may be adopted, so that the saving to be effected by adapting a vehicle to tar oil fuel will be 15 per cent. of the total expenses. Against this economy, there must be debited the extra cost of maintenance. It cannot be doubted that the net saving to be effected by the substitution of tar oil for petrol is very material, but a company with only a few vehicles in its employ probably would not be encouraged to spend money on adjustments and alterations for an economy of the order of 10 per cent.

In some respects, creosote would appear to be an ideal fuel for tractors. These engines are designed for consuming kerosene, and would operate satisfactorily on a light grade of creosote without further modification. The value of tar as a tractor fuel, however, is discounted

by the necessity for using it as quickly as possible after distillation. If creosote is allowed to stand for a few weeks it forms gums, which would cause endless trouble in the induction system of a motor engine. For this reason alone, it would not be wise to attempt the sale of tar oil as a power kerosene.

If creosote is ever adopted on a large scale as a motor fuel, it is to be expected that bus and lorry engines will be built for the consumption of other heavy fuels, such as kerosene. The mere fact that such developments have not yet taken place suggests that manufacturers do not consider, at present, that heavy oils can compete with motor spirit. Although power kerosene is retailed at 1s. 2d. per gallon in the capital cities, it can be landed into Australia for 7d. or 8d. per gallon. On a heat-value basis, this price is equivalent to the probable cost of production of a creosote-benzol mixture at the gas works. If a large demand were to arise for heavy motor fuels, therefore, oil companies would be in a position to sell kerosene at competitive prices.

It must not be overlooked that another competitor in the utility vehicle field is making fairly rapid progress in England and the Continent of Europe. Diesel engines are becoming popular for heavy duty, and more interest is being taken in these vehicles by bus companies and similar concerns than is being shown in creosote. Diesel engines possess all the advantages, and do not suffer from the limitations, of the creosote engine. It may be that in the near future the value of creosote as a motor fuel must be compared with Diesel oil instead of No. 2 motor spirit or kerosene. In such a competition, the advantage would undoubtedly rest with the petroleum fuel, for creosote itself cannot be used in a Diesel engine, and can only be adapted to the less efficient vaporizing oil engine.

6. Conclusions.

It has been demonstrated at Belfast and elsewhere that a motor engine can be adapted to consume tar oils instead of petrol. The performance of a vehicle on a heavy fuel is quite satisfactory, and the comparatively low price of creosote should appeal to transport companies and similar concerns operating large fleets of vehicles. The supply of creosote in Australia is limited to the larger cities, and only 4,000,000 gallons, approximately, could be made available at the present market price of tar oils. If a demand should arise for large quantities of heavy motor fuel, it is likely that kerosene also will be sold for the purpose. Creosote would then have no advantage in cost of production over other fuels. It is likely, therefore, that the consumption of tar oil as a motor fuel will be limited to the quantity which is at present being used for firing boilers and stills. This amount represents only a very small contribution to Australia's total requirements of motor spirit. It is very desirable that the utmost use should be made of home-produced fuels, but it would be very unwise to anticipate any considerable developments in the employment of creosote as a motor spirit.

To companies owning only a few vehicles, the possible saving in fuel would not justify the expense of the necessary alterations to the engine. The economies to be effected by large concerns, favorably situated for purchasing and using creosote, are fairly considerable, however, and co-operation with the gas companies on this subject should be to their mutual advantage.

Tasmanian Soils in Relation to Tree Growth in Plantations of *Pinus radiata* (*insignis*) and other Exotics.

By C. G. Stephens, M.Sc.*

The following article has been prepared from a rather full report written by Mr. Stephens, of the Division of Soils, primarily for the Tasmanian Forestry Department. In addition to giving detailed descriptions of the various types of soils on which pines have been planted in Tasmania, the report puts forward evidence in support of the contention that the acidity of the soils has a very important bearing on the well-being of the trees. As such a finding may have a much more general application than to Tasmanian soils, and in view of the somewhat widespread interest that is now being taken in Australia in the planting of pines and other exotics, it has been decided to publish the material that follows.—Ed.

Summary.

1. An examination of the soils of several forest plantation areas in Tasmania has been made.
2. Over the pH range (3.5–5.5) of the soils examined, the pH value was found to be much more significant than plant food values in controlling the vigour of the trees, low pH values in most cases being accompanied by the death of the trees.
3. Those soils of low pH value (3.5–4.5) were almost invariably very sandy, strongly podsolised soils, clay and silt being present in almost negligible quantities. These soils were also characterized by a heath vegetation, a feature of which was the predominance of *Sprengelia incarnata*.
4. Those soils of higher pH value (4.5–5.5) were characterized by a heavier texture than a sand, varying from a sandy loam to a denuded light clay. The vegetation on these soils was very different from that on the lower pH range, being of a rain or sclerophyll forest nature.
5. A correlation co-efficient of .8 was found between the vigour of *Pinus radiata* and the pH value of the soil.

1. General.

When the classification of the major soil types in Tasmania was commenced by the Division of Soils in 1931, the Departments of Agriculture and of Forestry undertook to co-operate in the work. The Forestry Department has an interest in the relationship between soil type and forest growth, and is particularly concerned as to the possibility of planting the poorer types of soils with exotic conifers and other trees. As a result of difficulties experienced with these poor soils in various parts of the State, the Department came to the conclusion that a careful investigation was desirable, with the result that the study which is the subject of the present report was undertaken.

Generally speaking, the areas utilized for softwood planting in Tasmania amount to several hundred acres, and have been what is termed third class land, often of the poorest quality, first and second class land usually being regarded as of greater agricultural than sylvicultural value. No extensive attempts have been made to plant the button-grass plains, which occur in large areas in the western half

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of the State, although a definite interest in that direction has been taken in them. On the poorer types of third class land, the trees have failed extensively. This is the case particularly at Strahan and Sisters' Hills, but where the plantings are on a different soil type—although included in the general broad classification of third class—namely, at Queenstown, Beaconsfield, and a small portion of Sisters' Hills, quite good results have been obtained.

At Strahan the plantation is situated entirely on ancient sand dunes which have been extensively re-worked, and which, except near the shore, and where they have been broken up to form sand-blows, retain practically no resemblance to the beach sand from which they are derived. The slopes of these dunes vary from gentle to moderate.

Sisters' Hills is situated on an extensive area of pre-Cambrian sandstone, the topography of the country being very steep, except for some areas of gentler slopes in some of the broader valleys.

Both the Beaconsfield and Queenstown areas are situated in country the rocks of which have a very complex petrographic nature. At Beaconsfield there are present gabbro, serpentine, slates, and schists, as well as areas of more recent rocks. At Queenstown the predominant rocks are felsites, gabbro, and serpentine. The slopes on the average, in both cases, are moderate, though flats and steep slopes both occur.

Thinking that the failure of the trees on certain areas might be due to the absence of mycorrhiza-forming fungi, the Forestry Department inoculated some of the areas at Sisters' Hills with soil from more successful areas. This produced no result.

Although the literature on the subject is somewhat indefinite, it is generally considered that the formation of mycorrhiza is essential for the successful growth of pines. With this idea in mind, one dozen two-year-old *Pinus contorta* plants of various heights and shades of green and yellow were handed to Mr. W. M. Carne, of the Division of Plant Industry, for examination. He reported that abundance of root growth, abundance of mycorrhiza, and mycorrhizal activity in general decreased as the trees became more yellow and, with one notable exception, as the size of the trees decreased. The exceptional tree, however, fitted in the colour gradient. Mycorrhiza was present in all cases.

Hence it is practically certain that the failure of the trees in this case is not due to the absence of mycorrhiza-forming fungi. However, it is possible that the soil conditions themselves, by controlling the abundance of the fungi, indirectly control the vigour of the trees.

2. Soil Types and Analytical Data.

The full report contains detailed descriptions of the various types into which the soils have been classified, and also the results of mechanical and chemical analyses. Accounts of the native vegetation occurring on the various types are also given.

Because of the indications presented by the state of the trees and the type of natural vegetation present, it was decided to regard the determinations of soil acidity (pH) as the major part of the investigation, and as being likely to yield the most important results. Accordingly, nearly three hundred pH determinations in all were made, the quinhydrone electrode being used throughout. The results are classified

in Table 1. In addition, certain indications were noticed that pointed to a probable deficiency of potash, phosphates, and nitrogen in most of the soils. Hence both available potash and phosphate and total nitrogen were determined on samples from each of the soil types.

All values for available phosphate for surface soils except one were either low (0.0025 per cent.) or very low (0.00012 per cent.), but one value (0.0066 per cent.) approached a moderate figure. Similarly, all values for available potash for surface soils were either low (0.0050 per cent.), or very low (0.0012 per cent.). Some of the latter values may be regarded as extremely low.

The figures for total nitrogen varied from low (0.0364 per cent.), to high (0.3388 per cent.) values.

3. Conditions of the Trees and their Correlation with Analytical Data.

At Strahan, on soil type S1, the trees planted seem to be doing very poorly. Over the whole area, the trees are of a decidedly yellow colour, and on the average have attained a height of approximately only 18 inches for several years' growth. Quite a percentage are dead, but occasional trees, in hollows, seem to have done fairly well. On two areas that were ploughed before planting, a little improvement in the height was noticed. In addition, some work has been carried out on a few experimental plots. Several fertilizers have been used and, in the case of bone and superphosphate together, superphosphate alone, blood and nitrate together, blood and superphosphate together, and blood and bone together, all trees show some increase in height, being in a few cases up to 30 inches high, but they are still yellow and well below normal growth. On one plot where lime had been used, no effect was noticeable. On soil type S2 the trees show a slight improvement on the above, being of a greater average height in general, and of a better colour, although not a normal green.

At Sisters' Hills, on both soil types SH1 and SH2, the trees have failed consistently, those on type SH2 being much the worse. All trees are yellow, those on type SH2 being particularly bright in colour, and in both cases they are of a very low height, those on SH2 again being the worst. No very definite general figure for height is possible, owing to the different species and ages of the trees planted, and the fact that many plots were frequently refilled. On the whole, the oldest of those that have survived have made very poor growth. A large proportion of the trees on SH1, and a very large proportion on SH2, have died. Some of the trees have been planted on mounds about 6 inches high—a practice that seems to have effected a slight improvement. Where some stump has been burnt in the ground and the tree planted in the remains a noticeable improvement in height suggests that potash is somewhat deficient in these soils—an assumption verified by the analytical data. The growth of the trees on type SH3 is particularly good, both in height and colour.

At Beaconsfield, on type B1A, the growth of the trees on the whole may be classed as good, e.g., trees eight years old are in many cases over 20 feet high. There is some variation in height, but the colour is generally normal. The same remarks apply to B1B, except that there is rather more variation in height. On type B2 there is considerable variation, from quite poor results in both colour and height, to quite

normal growth. Type B3 exhibits the worst results at Beaconsfield, there being generally a variation from very poor to very fair results, colour and growth being in some cases as bad as at Sisters' Hills on type SH1.

On both types, Q1 and Q2, at Queenstown, the trees seem to be making very fair growth, and are almost normal in colour. In this case, only *Pinus pinaster* is considered, as the other two species planted appear to be suffering to some extent from the small percentage of sulphur dioxide* still in the atmosphere, although they continue to make fair growth. *P. pinaster* does not appear to be affected.

Some leaf fusing and *Chermes* were noted on the various areas, particularly at Beaconsfield.

The data and analytical results are classified in Table 1.

4. Conclusions.

The major results of the investigation seem to indicate that it is useless to attempt to plant exotic and other species of softwoods on natural soils with a pH value of less than 4.0, and that on soils with pH values between 4.0 and 4.5, failure is comparatively certain or, at best, on the better textured soils only fair results will be obtained. In the latter pH range, an efficient drainage scheme and/or a different method of planting, e.g., an elaboration of the mound planting tried at Sisters' Hills, may improve results, especially on the better soils. Generally speaking, the soils with pH above 4.5 should give good results, and those above pH 5.0 excellent returns. The value pH 4.0 may be regarded as the limiting value for the survival of exotics in general, although it was continually noticed that some species withstood greater acidity (lower pH) better than others. This was particularly noticed in the case of *Pinus contorta*, which seems to do comparatively well down to pH 4.0; e.g., on an area from which the samples were all between pH 4.0 and 4.5, and where *Pinus radiata*, *Picea stichensis*, *P. excelsa*, *Larix europea*, *Sequoia sempervirens*, and *Tsuga albertiana* had all failed, *P. contorta* is showing up splendidly, and putting forth good shoots. It is possible to observe numerous examples of the above phenomena, but there is need for further elaboration of the work to place the species in some definite order of tolerance to acidity.

Another prominent fact is the marked relationship between the physical characteristics of the soils, and the growth of the trees. In all cases where the soils are completely podsolised sandy soils, the trees have grown very poorly. Since such completely podsolised sands are, under the climatic conditions prevailing in Tasmania, naturally very acid in reaction, then the connexion between the growth of the trees and the texture of the soil can be readily followed. Where the trees have been successful they are almost invariably on soils heavier than sands.

Despite the observations in the field having shown that the trees will respond to increments of phosphatic, potassic, and nitrogenous fertilizers, an examination of the estimations of the plant foods and total nitrogen on the samples from the various soil types indicates that the vigour of the trees is probably not very largely determined by the amount in which they are present, but rather that the pH value is more significant. For example, type B3 is high in nitrogen, while B1A is low; but the trees on

* From the Mt. Lyell smelters.

TABLE 1.

Soll.		Trees.			Reaction.		Plant Nutrients.		
Type.	Texture.	(a) Height.	(b) Colour.	(a) and (b) Variation.	Mean pH.	Standard Deviation.	Available P ₂ O ₅ .	Available K ₂ O.	Total Nitrogen.
S1	Poor—sandy	Poor	Yellow	Very little	< 4.5	Small	Very low..	Very low..	Low
S2	Poor—sandy	Poor—fair	Slight yellow	..	< 4.5	..	Low	Very low..	Low
SH1	Poor—sandy	Poor	Yellow	Very little	< 4.5	Small	Very low..	Very low..	Low
SH2	Poor—sandy	Very poor	Very yellow	Very little	Much < 4.5	Small	Very low..	Very low..	Moderate
SH3	Good—loamy	Very good	Green	..	Much > 4.5	..	Moderate	Low	High
B1A	Good—sandy- loam	Good	Green	Some	> 4.5	Moderate..	Low	Low	Low
B1B	Very fair—clay- loam	Good	Green	Some	> 4.5	Moderate..	..	..	Low
B2	Fair—fine-sand	Very fair..	Green	Big	> 4.5	Large	Low	Low	Low-moderate
B3	Poor—sandy	Poor	Yellow	Big	< 4.5	Large	Low	Low	High
Q1 and Q2	Very fair—silty..	Very fair..	Green	..	= 4.5	..	Low	Very low..	Low-moderate

B1A are much better than those on B3. Since both phosphate and potash are low in both types, this difference is most probably due to the difference in pH values, that of B1A being higher than that of B3. Owing to the general poorness of all soils except SH3 in phosphate and potash, these figures are not so readily interpreted, but the fact that trees show quite good growth on such soils as B1A, which are as poor in phosphate and potash as some of the soils where the trees are doing very poorly, indicates that the paucity of these plant foods is by no means the limiting factor in the growth of the trees.

This conclusion as to the importance of an optimum pH range, rather than an abundance of plant foods, was verified by the strength of the correlation of the vigour of *Pinus radiata* for which sufficient data was available with the pH values of the soil samples taken from the hole in the immediate vicinity of which the height of the young trees was estimated.

To overcome the difficulties associated with curved regression lines and partial correlation co-efficients caused in this case by the different ages (0-9 years) of the trees measured, and the fact that the age at death, as distinct from age at date of observation, was not known, the heights of the trees at different ages were compared as ratios with the heights at corresponding ages of an arbitrary standard *Pinus radiata*, thus reducing the problem to one involving direct correlation and straight line regression. The ratio of the heights was defined as the vigour of the trees. The heights of the standard tree at various ages are shown in the following table:—

Age (years)	..	..	0	1	2	3	4	5	6	7	8	9
Height (feet)	..	..	1	2	4	6	9	12	15	19	23	27

Whatever the age at death, or date of observation, if the great majority of the trees near the hole were dead, and the remainder at a standstill, the vigour was taken as <.2, and placed accordingly in the correlation table, together with the other values of which there were eighty in all. The following is the correlation table:—

		Reaction (pH).												
		3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	Total.
Vigour.	1.6													
	1.4											$\frac{1}{2}$	$\frac{1}{2}$	1
	1.2								1		1			2
	1.0				$\frac{1}{2}$	1		$2\frac{1}{2}$	$1\frac{1}{2}$	2	$\frac{1}{2}$			8
	.8				$1\frac{1}{2}$	2	$\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	1				10
	.6				2	3	2	1	5	$\frac{1}{2}$				$13\frac{1}{2}$
	.4		1		3	$3\frac{1}{2}$	5							$12\frac{1}{2}$
	.2			2		1	3							6
	0.0	$2\frac{1}{2}$	6	$3\frac{1}{2}$	6	$7\frac{1}{2}$	$1\frac{1}{2}$							27
Total	$2\frac{1}{2}$	7	$5\frac{1}{2}$	13	18	12	$6\frac{1}{2}$	$9\frac{1}{2}$	$3\frac{1}{2}$	2	$\frac{1}{2}$		80	

It is obvious from the above table that there is a marked positive correlation between pH value of the soil and the vigour of the trees. The angles formed with the axes by the two regression lines calculated and plotted from the above table give a positive correlation co-efficient of .8. From Fisher's tables, the co-efficient for the .05 level of significance and 78 degrees of freedom (80 double entries) is .214, so that the result of .8 is undoubtedly significant.

The arbitrary standard *Pinus radiata* was suggested by the Conservator of Forests, Hobart, and its growth curve forms an almost exact fit to the equation $(h - 1) = k.a.^{3/2}$, where $k = 0.96$, h = height in feet, and a = age in years. Other arbitrary standard trees, if used, would, by virtue of their different total heights, merely cause a change of scale of the regression lines. If the yearly growths did not fit the above equation, then there would be a re-arrangement of the points about the regression lines, but they would actually change the position of the lines which are fitted by the law of least squares, little, if any.

Hence it appears that over the pH range (3.5-5.5) of the soils examined, in the case of *Pinus radiata* at least, and there is every indication that it is true of many other species, the pH value of the soil is of major importance in determining the vigour of the trees.

5. Acknowledgments.

During the course of the work, the author was greatly helped in many ways by the Conservator of Forests, and several members of his staff. Also Professor J. A. Prescott, Chief of the Division of Soils, Council for Scientific and Industrial Research, helped considerably by his advice and criticism of the various phases of the work. Professor E. J. G. Pitman, of the University of Tasmania, looked over the mathematical portion of the work. To them the author tenders his sincere thanks.

PLATE 1.

(The Animal Health Research Station, Townsville. See page 61.)

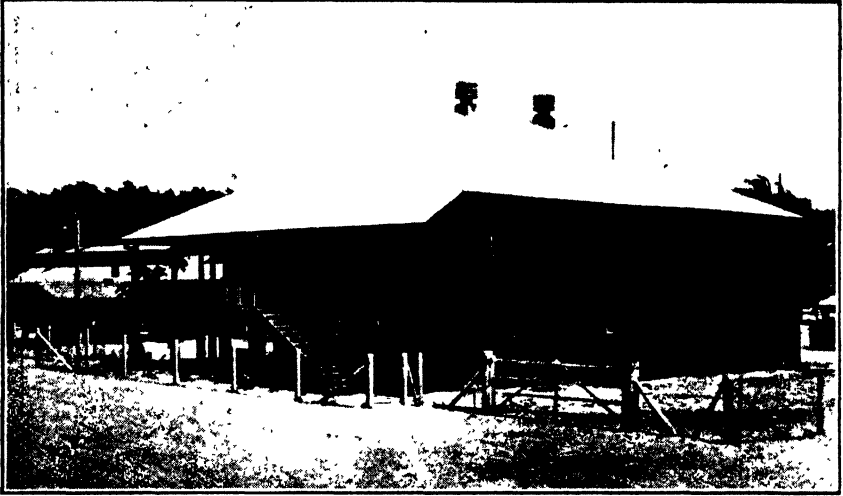


FIG. 1.—General view of laboratory building from south-east.



Fig. 2.—Isolation paddocks for experimental cattle. Erected in the coconut palm grove with each pen carefully buffered. A group of cattle used in contagious bovine pleuro-pneumonia is seen. November, 1932.

PLATE 2.



FIG. 3.—General laboratory (bacteriological and biochemical). Unfortunately the photographer included the then incompleted stairway. November, 1932.



FIG. 4.—Post-mortem room in concrete annexe. November, 1932. The unique design was reproduced from Continental literature.

NOTES.

The Animal Health Research Station, Townsville.

In recent issues of this *Journal* (e.g. Vol. 5, No. 2, p. 131, and Vol. 5, No. 3, p. 193), references have been made to the cattle investigations in which the Empire Marketing Board, the Queensland Government, Queensland cattle producers, and the Council are co-operating. The main laboratory in which this work is centred is at Oonoonba, some 6 miles outside Townsville, and was made available for the work by the Queensland Government. Subsequently, however, various modifications were made to the various buildings in order to make them more suitable to the particular programme of investigations mutually agreed upon by the co-operating parties. Some recent photographs of the Station have now been obtained, and four selections from them are reproduced in Plates 1 and 2 (facing page 60).

The Thomas G. Sloane Collection of Insects (Coleoptera).

The late Mr. Thomas G. Sloane, a well known sheep breeder of "Morilla" Station, near Young, N.S.W., was a keen collector of beetles, and became one of the leading specialists in the world on the great group of Caraboidea or Ground Beetles and their allies. It had been his intention to retire to Canberra and spend the last years of his life working at his favorite hobby, and he had expressed his intention of leaving his collection to the Museum of the Division of Economic Entomology, C.S.I.R. His death occurred before he could give effect to his wishes, but Mrs. Sloane has very generously donated the collection to the Council.

The collection consists of many thousand specimens of Caraboid beetles and is divisible into two main sections—(a) Mr. Sloane's collection proper, containing only Australian species, and housed in a large cabinet; (b) the famous van der Poll collection, containing Caraboidea of the whole world, in about 300 continental cartons, purchased by Mr. Sloane during his last visit to Europe. In the Australian portion of the collection there are a large number of valuable type specimens.

Besides the collection, the Council has secured a complete autographed and annotated set of Mr. Sloane's publications, fifty-five in number, which will be of very great value to any specialist wishing to make use of the collection.

Entomological Investigations—Gift of £500 by Sir MacPherson Robertson.

The Council has recently received a very generous gift of £500 from Sir MacPherson Robertson, the well-known confectionery manufacturer of Melbourne. The gift consists of £200 for capital expenditure and £100 per annum for three years. It is known that Sir MacPherson would welcome researches into insect pests of stored food products, but nevertheless he has made his gift quite unconditionally.

It is proposed to utilize the capital grant for the erection at Canberra of temperature and humidity control apparatus in which entomological studies of the nature Sir MacPherson has in mind may be undertaken. Plans for such apparatus are now being prepared.

The Blowfly Problem.—Forthcoming Comprehensive Report.

Elsewhere in this issue (page 70) a brief reference is made to the forthcoming publication of the Joint Blowfly Committee's report on the blowfly problem.

This Committee is a body that has been established by the Council and the New South Wales Department of Agriculture acting in conjunction. Its main purpose is to co-ordinate the blowfly researches of the two bodies, and to advise generally in regard to that work or to the initiation of investigations into other aspects of the main problem. It is constituted as follows:—

- Dr. J. A. Gilruth, Chief, Division of Animal Health, C.S.I.R. (Chairman),
- Dr. R. J. Tillyard, Chief, Division of Economic Entomology, C.S.I.R.,
- Dr. H. R. Seddon, Director of Veterinary Research, N.S.W. Department of Agriculture, and
- W. B. Gurney, Entomologist, N.S.W. Department of Agriculture, with Dr. I. M. Mackerras, of the Division of Economic Entomology, C.S.I.R., as Secretary.

At an early stage after the Committee's formation, it considered that the publication of a statement which would summarize the work already done on the problem and the present stage of knowledge of the problem was advisable. It was realized that such a statement, if published, would be of value, not only to the sheep-owner, but to research workers generally throughout Australia and other countries.

This suggestion was approved and a report has now been prepared. It will be ready for publication almost immediately. It is written in language as simple as possible, consistent with exactitude, and comprises 136 pages of subject-matter, together with a number of text figures of larvae, traps, &c., a number of photographs of interest, and a coloured frontispiece showing each individual species of blowfly associated with strike. It will be possible, by reference to this coloured frontispiece and to the accompanying descriptions, for any one to determine the nature and importance of any blowfly which he may capture. The various sections of the report are as follow:—(i) the blowflies concerned, (ii) description of strike, (iii) origin and spread of strike, (iv) earlier scientific investigations, (v) later scientific investigations, (vi) geographical and seasonal distribution of flies, (vii) blowfly biology: habits and life-histories, (viii) blowfly biology: relation to environment, (ix) factors influencing fly abundance, (x) susceptibility of individual sheep, (xi) general waves of fly-strike, (xii) general observations of measures for combating strike, (xiii) crutching, (xiv) jetting, swabbing, and dipping, (xv) dressings, (xvi) breeding to reduce susceptibility, (xvii) fold removal operation, (xviii) biological control, (xix) trapping, (xx) carcass treatment, (xxi) facilities for research, and (xxii) scope of the present investigations.

The report will be issued as a joint publication by the two co-operating parties, but at the same time will be incorporated by each organization in one of its regular series of publications, namely, the Council's series of Pamphlets and the Science Bulletin series of the New South Wales Department of Agriculture.

The printing of the report has been rather costly, and it will be necessary to make a small charge (1s. 6d. per copy).

The Occurrence of Anaplasmosis in Cattle in North Australia.

Hitherto, it has generally been accepted that the only blood parasite transmitted by the cattle tick (*Boophilus microplus*) in Australia is the piroplasm which produces the disease known as redwater or tick fever. For some considerable time, however, there has been very good reason for believing that other blood parasites existed, these being also transmissible from affected to healthy animals by the same tick and possibly by other vectors. One of these parasites is known as the anaplasma, discovered by Sir Arnold Theiler in 1910 in cattle in South Africa, and since determined to have a very wide distribution throughout the tropical and sub-tropical areas of the world. Anaplasmas are known to exist in South, Central, and North Africa, Asia Minor, the East Indies, and North and South America.

This parasite takes the form of a minute spherical body usually found within and close to the margin of the red blood corpuscles. It is quite different in appearance from the piroplasm, which is usually pear-shaped. In the past, its existence has possibly been overlooked because it produces a disease very similar to redwater, and its appearance in the blood in association with the piroplasm has caused observers to regard it as possibly only a variety of the latter organism.

Dr. J. Legg, of the Animal Health Research Station, Townsville (re the establishment of which see this *Journal*, Vol. 5, May, 1932, p. 131), has for some time suspected that the anaplasma exists in North Queensland, but prior to the inauguration of the new régime the necessary facilities for pursuing these investigations were not available. Since his return from South Africa, a few months ago, however, he has addressed himself to the problem, and by a series of experiments has determined (i) that the anaplasma exists in Australia, often concurrently with the piroplasm, but from which it may be dissociated; (ii) that it is capable of producing a diseased condition of the host that may result in death; and (iii) that immunity to the one blood parasite does not imply immunity to the other.

The discovery is of importance chiefly in connexion with the immunization of healthy cattle introduced into the tick-infested areas of the North.

The presence of two diseases, both tick conveyed, on an individual property may account for the so-called "relapse" which may occur when cattle immunized against the redwater piroplasm are exposed to tick infestation, the "relapse" in this instance being due to anaplasmosis inoculated by the tick in the natural manner.

When one considers the long period of incubation which frequently occurs with anaplasmosis, an explanation is given to the "secondary reactions" which may occur after inoculation for redwater, these "secondary" or delayed reactions being due to the presence of the anaplasma in the blood used for inoculation purposes.

There is the possibility that tick-infested areas exist whether neither of the parasites exist, or where one alone may be present.

Dr. Legg's report will shortly be published by the Council as a special pamphlet.

White Ant Investigations in North Australia.

Mr. G. F. Hill, of the Division of Economic Entomology, returned towards the end of last year from a three months' stay in Darwin, where he went for the purpose of carrying out some investigations into the control of the largest and most destructive Australian termite (white ant), namely, *Mastotermes darwiniensis*. Particular attention was given to the insect's attack on dwellings and on living trees, and a considerable proportion of the work concerned the effect of various poisons.

Numerous tests were made with baits of sawdust and other cellulosic material after treatment with various poisons and with and without the addition of supposed attractive substances. It was found, however, that sawdust from *Eucalyptus gigantea* was more attractive than any other material tested. When such sawdust was mixed with from 1 per cent. to 3 per cent. of arsenite of soda, termites were destroyed, but it was found impossible to free an infested building of the insects in this way.

Fumigants and dusts such as paradichlorbenzene, sodium fluoride, Paris green, cyanogas, &c., were used in walls traversed by the insects, and also in the "tubes" or tunnels leading to the main nest. (Incidentally the nest of a colony of *Mastotermes* is extremely difficult to find and may be 100 yards or more distant from the site where insects are obviously present, the path between the nest and feeding place being an underground tortuous "tube"). Most of these materials were found to kill white ants readily enough, but their effects soon wore off, and other members of the colony soon returned. Paris green, however, was found to be very satisfactory. In one case, for instance, an occupied tube extending from the ground up the concrete foundation of a building was broken, and Paris green blown into it. For some weeks the termites which were left in the timber attempted to reconstruct the tube to allow of their return to the soil, but each attempt failed, and the result was the death of a great number of insects.

In the neighbourhood of Darwin, indigenous and introduced fruit and ornamental trees are frequently attacked by white ants. It was found, however, that Paris green used as a dust and blown into the centre of an infested tree from an auger hole bored into the centre at about 18 inches from the ground was quite effective. In all, about 100 trees, including about 46 citrus trees, and many mangos, poincianas, and indigenous Acacias were treated—in all cases with complete success. It is expected that the treatment will remain effective for many years.

In conclusion, Mr. Hill's work was greatly facilitated by the Australian Investment Agency, which, through its General Manager, Mr. C. W. D. Conacher, gave £75 towards the cost of the work as well as laboratory and other accommodation at Darwin, and clerical and manual assistance.

Wood Taint in Butter—Experimental Shipments.

In a previous issue (Vol. 5, Feb., 1932, page 1), an account of the Council's investigations into the problem of wood taint in butter, and of the spray treatment that has been developed for controlling it, was

given. Further tests of the process are now being carried out by means of small experimental shipments of sprayed boxes which are being used as part of an ordinary consignment of export butter.

Two timbers, namely, *Pinus radiata* (*insignis*) and hoop pine, are being employed in the tests. Boxes made of the former timber are being forwarded to London by the South Australian Farmers' Co-operative Union. The first shipment from South Australia, consisting of 90 boxes, left Australia early in 1932. The results of the London inspections were, on the whole, satisfactory, although a small amount of taint in the butter near the edges of the boxes was found. The boxes of this particular shipment, however, consisted of undressed timber, which did not give the treatment such a chance of success as if dressed timber had been used. Further shipments of boxes made up of dressed timber left South Australia in September and October last, and the results of the London tests should soon be available.

Small experimental shipments of butter in boxes from sprayed hoop pine have also been sent from Queensland by Messrs. Hancock and Gore. The first of these left Australia in August last, and was followed at short intervals by five others. The results of the London inspections of the first shipment have just become available through the courtesy of the Department of Commerce, being contained in a report of the Department's Dairy Officer located in London. The report reads as follows:—

“A consignment of butter, packed in specially prepared boxes *ex* the s.s. *Bendigo*, was examined at the warehouse of Messrs. Foley Bros. on 20th October. A selection from the marked boxes was made of an equal number of treated boxes comprising veneer and sawn timber boxes. For comparative purposes, a number of untreated boxes were also brought to the warehouse.

“Each box was emptied and the box and contents carefully examined. It was noted that in every instance the treated boxes gave off no smell from the inside and had a clean impervious surface. The edges and other surfaces of the butter were carefully inspected, and only in rare instances was the faintest trace of taint to be found on the most exposed of the edges. In one instance the paper had got doubled back, exposing several square inches of unprotected butter, but no trace of taint could be found. On this occasion, there was a most distinct difference between the treated and untreated boxes. While the treated boxes were free from smell and the butter on all surfaces almost completely free from taint, the untreated boxes, especially the veneer type, smelt like new leather. The taint could be found on most surfaces of the butter, but was particularly noticeable on edges, top side and bottom.

“Should subsequent examinations of other consignments yield such satisfactory results, a considerable step towards the elimination of timber taint will have been made, but at this stage one cannot anticipate the result of future examinations.”

In all cases of these experimental shipments, a few boxes are retained in Australia and opened up at about the time the main shipment should reach London. The butter they contain is then tested for wood taint. The results of this work to date have, as would be expected, been in line with the results of the London inspections.

A new Apparatus for Treatment of Wounds and Fly-struck Areas on Sheep during Shearing and Crutching Operations.

(Contributed by Dr. J. A. Gilruth, Chief, Division of Animal Health.)

The varied sounds of a shearing shed are frequently punctuated by the cry "Tar." Forthwith a youth speeds to the source, and dabs more or less ineffectually a black paste from an uninviting pot with a stubby brush on to a wound more than usually severe made by the shears or the hand pieces of the shearing machine. Often the operation is perfunctory. The application is supposed to sterilize the wound, stop bleeding, and promote healing. Ordinarily its effect is negligible, beyond a tendency to ward off flies. It has struck many observers as being an unsatisfactory procedure, but time does not permit of the more careful antiseptic treatment of such wounds which, after all, are comparatively rarely attended with serious results. Perhaps no animal could suffer such frequent wounding of the skin in similar surroundings with the same impunity as does the sheep. From time to time, however, outbreaks of blood poisoning and of tetanus follow, while it has been abundantly demonstrated that the most common means of entrance to the system of the microbe responsible for "cheesy glands" (caseous lymphadenitis) is through wounds inflicted during shearing. Therefore, if an effective, economical, and handy method of applying an antiseptic were available, many a pastoralist would adopt it and with benefit.

Such a method has recently been devised, and I have had the opportunity of witnessing it in practical operation at the shed of Mr. F. D. McMaster of "Dalkeith," while sheep were being crutched and treated for strike when necessary.

The apparatus consists of a small air-pump (driven from the engine) and a cylinder provided with a gauge placed where the attendant can observe the pressure which is maintained at from 50 to 75 lb. per square inch. From this cylinder, a $\frac{1}{2}$ -inch pipe is led throughout the shed about 10 feet above the floor and attached to the uprights of the holding pens. From this horizontal pipe three down pipes for each group of ten stands descend at intervals to within 2 inches of the floor. At the end of the down pipe is affixed about 12 feet of rubber tubing which leads to a spray-gun similar to those used for the spraying of paint. The gun is fitted with a trigger which, when pressed, permits a spray or a jet to be emitted at the will of the operator. While not in use, the gun rests on a convenient bracket out of the way. When the shearer calls out "Tar," the boy grasps the nearest gun and rapidly and effectively sprays the wound with the antiseptic solution contained in the gun. For wounds at shearing time, a 1 to 7 solution of phenyl is employed at "Dalkeith," but during crutching, when struck sheep may be found, the solution used is slightly stronger—1 part of phenyl to 6 of water. I treated personally a number of fly-struck sheep with this apparatus, and found it everything one could desire for rapidity of treatment as well as effectiveness in destroying the maggots, while the quantity of fluid necessary was reduced to a minimum. Contrary to general expectations, the flexible tube is never in the way, and the shearers engaged in crutching were unanimous in their expressions of approval of the new method.

The cost of the installation complete is relatively moderate; when once established, depreciation is small and the cost of operating negligible. No extra staff is required. It should be a special boon to all pastoralists who are liable to find a percentage of sheep struck when shearing or crutching.

Recently, the members of the Joint Blowfly Committee at Canberra had an opportunity of observing a demonstration on the treatment of fly-struck sheep, with a portable apparatus attached to the motor car of the maker. They expressed the opinion that the use of this apparatus would be very much more efficacious for the treatment of wounds at shearing time, and the treatment of struck areas when crutching, than the methods hitherto in use.

The Investigation of "Coast Disease."

The Chief of the Council's Division of Animal Nutrition (Sir Charles Martin) has recently made some suggestions to the Executive Committee of the Council in connexion with the problem of "coast disease" which causes difficulties to raisers of sheep and cattle in certain parts of Australia. He points out that the problem exists on some thousands of square miles of coastal districts to the south of Australia extending from King Island in the east to beyond the western border of South Australia in the west.

As Sir Charles puts it "the general story dating back 50 years is that although stock may be fattened upon calcareous country during the spring and early summer, if kept upon it for more than a few months they become debilitated and die, but if removed to much poorer "ironstone" heath country on the elevations adjoining the calcareous flats they recover their health but become, from scarcity of food, poor. Sheep farmers find it impossible to run their business unless they have access to ironstone country."

After discussing previous work on the problem and indicating that the conclusions drawn from such work are very divergent, Sir Charles expresses the opinion that there is a variety of maladies included in the term "coast disease" and that as a first step in the solution of the problem these individual conditions should be sorted out and classified. From his own observations to date, he considers that the term has been extended, *inter alia*, to the effects of parasitism, a nervous disease producing ataxia called rickets by the farmer, a lethargy with muscular weakness proceeding to emaciation and death and affecting animals which may be in apparently good nutritive condition, and maladies due to various degrees of general and mineral starvation.

He suggests that a small committee composed of people experienced in different branches of science be set up in South Australia to direct an inquiry into the whole problem.

The Executive has approved of the above suggestion and is now making the necessary approaches with a view to having the committee formally established.

Investigations with New Apple Stocks.

As a result of his visit to Australia a year or so back, Mr. R. G. Hatton, Director of the East Malling Research Station, reached the opinion that it would be well worth while if some tests of apple stocks other than the Northern Spy were carried out in Australia. He felt that there was a possibility that a number of problems of the local apple

industry were due to the general use of the Northern Spy stock and that some of the stocks developed at East Malling might be more suitable for some Australian conditions. In addition, Mr. Hatton has at all times made it clear that he would be glad to accommodate selected Australian graduates whom it might be desired to send to East Malling for experience in that Station's methods.

Accordingly, when towards the end of last year the Queensland Committee of Direction of Fruit Marketing approached the Council in connexion with horticultural investigations in the Stanthorpe district and offered financial assistance in that work, the opportunity was taken to send such a graduate for a year's stay at East Malling. The graduate in question is Mr. L. A. Thomas, M.Sc., and he is now at the Station on a studentship awarded him by the Trustees of the Science and Industry Endowment Fund. On his return to Australia, he will be located at Stanthorpe as an officer attached to the Division of Plant Industry. The Committee of Direction will then undertake the responsibility of providing his salary for a period of three years.

He has recently made arrangements for sending out to Australia at a fairly early date a selection of what are considered suitable East Malling stocks. It is proposed to plant these in the Stanthorpe district in two or three different situations. It is hoped that the necessary small blocks of land will be provided by local producers through the Committee of Direction.

The Catalogue of Scientific Periodicals—Supplement.

The "Catalogue of Scientific and Technical Periodicals in the Libraries of the Commonwealth" was published by the Council some three years ago, the entries contained in it, however, covering information given by libraries up to the end of the year 1928. As pointed out in a previous issue (Vol. 3, page 125, 1930), it is particularly useful in a country of such large distance as Australia for research workers and others to be able readily to ascertain which libraries contain the particular periodicals they desire to see, especially as such periodicals are often comparatively rare. It was to meet that purpose that the Catalogue was originally prepared and printed.

At the time, it was realized that for the Catalogue to be maintained at its full value it would be very necessary to keep it up to date by means of periodical supplements. Information *re* amendments and additions is now being obtained from the co-operating libraries with a view to publishing the first supplement at an early date. A large proportion of this information has, in fact, already been obtained and indicates that this first supplement will need to be somewhat voluminous and that it will approach in size one-quarter that of the original Catalogue.

The estimated cost of preparing and publishing a supplement of this size amounts to some £400. Owing to the present restricted financial resources of the Council, it was obvious that publication would be delayed for a considerable time if the Council bore the whole of the cost involved as it did in the case of the main Catalogue. Under the circumstances it was decided to approach various scientific organizations such as

Universities, Royal Societies, the Australian National Research Council, the Australian Association for the Advancement of Science, the Australian Chemical Institute, the Institution of Engineers, Australia, the British Medical Association, Chambers of Manufactures, the Institution of Architects, the larger Public Libraries, Field Naturalists Societies, and the Australian Museum, for contributions.

The response has been very gratifying and already some £250 has been promised with a few further answers yet to come. It has accordingly been decided to proceed with the editing and publication of the supplement in question as soon as possible.

Copies of the main Catalogue (price 10s.) are still available on application to the Council or to Messrs. Angus and Robertson, Sydney.

Recent Publications of the Council.

1. Since the last issue of this *Journal*, the following Bulletins and Pamphlets of the Council have been published :—

Bulletin No. 71.—"Investigations on Irrigated Pastures."

1. The Yield and Botanical Composition of an Irrigated Permanent Pasture under Various Systems of Pasture Management, by A. E. V. Richardson, M.A., D.Sc.
2. The Chemical Composition of Irrigated Pastures at Wood's Point, South Australia, by H. P. C. Gallus, B.Sc.

The bulletin contains two reports of work on mineral deficiencies in pastures carried out under the co-operative arrangement entered into by the Empire Marketing Board, the Council, and the Waite Agricultural Research Institute. The first report deals with the results of studies into the yield of a permanent pasture under irrigation, into the effect of cutting the pasture at intervals of 28 and 56 days, and into the effect of fertilizers. The stock-carrying capacity of 70 acres of a permanent pasture sown at the same time as the experimental area and alongside it was 16.2 sheep per acre throughout twelve months.

The second report deals with the chemical composition of the experimental irrigated pastures mainly from the point of view of their nitrogen and phosphoric acid content.

Pamphlet No. 36.—"Fibre Boards: Their Uses and the Possibilities of their Manufacture in Australia," (Division of Forest Products—Technical Paper No. 6), by R. F. Turnbull, B.E.

The pamphlet discusses the results of a study that has been made by Mr. Turnbull into the possibilities of using Australian hardwoods for the manufacture of fibre boards and the economic possibilities of the industry in Australia. A description is given of the various types of fibre board in common use in other parts of the world; a history of the growth of the industry is also included. It is shown that the present consumption of such material in Australia, is about 9,000,000 sq. ft. or 1.4 sq. ft. per head of population as compared with a corresponding figure of 7.5 per head for the United States of America. From these figures it is

judged that the Australian demand could no doubt be stimulated considerably. A plant suitable for Australia is described, and the estimated cost for an annual production of 27,000,000 square feet is given as 10s. 6d. per 100, the corresponding figures for annual productions of 9,000,000 square feet and 6,000,000 square feet being 14s. 9d. and 21s. respectively. The conclusion is arrived at that if by the establishment of a sufficiently large plant, production costs are kept low, the enterprise would warrant every encouragement.

Forthcoming Publications of the Council.

At the present time the following future publications of the Council are in the press:—

Bulletin No. .—"A Soil Survey of the Nyah, Tresco, Tresco West, Kangaroo Lake (Victoria) and Goodnight (New South Wales) Settlements," by J. K. Taylor, B.A., M.Sc., F. Penman, M.Sc., T. J. Marshall, B.Sc. (Agr.), and G. W. Leeper, M.Sc.

Bulletin No. .—"Varieties of Wheat in Australia—A Catalogue with Pedigree or Source and a Genealogical Chart showing the Relationship of the more Important Varieties," by J. R. A. McMillan, M.Sc.

Pamphlet No. 37 of the Council for Scientific and Industrial Research and *Science Bulletin No. 40* of the New South Wales Department of Agriculture. "The Sheep Blowfly Pest in Australia." Report No. 1 by the Joint Blowfly Committee (appointed by the Council for Scientific and Industrial Research and the New South Wales Department of Agriculture). Editors R. J. Tillyard, M.A., D.Sc., F.R.S., and H. R. Seddon, D.V.Sc.

Journal of the Council for Scientific and Industrial Research.

Vol. 6.

MAY, 1933.

No. 2.

Viticultural Investigations—Commonwealth Research Station, Merbein.

1. Introduction.

At the present time, Australia is the third most important country from the point of view of the production of dried vine fruits, and in addition is the largest supplier of such fruit to the markets of Great Britain. Her annual production now normally varies from 60,000 to 65,000 tons, this amount corresponding to a total return of over £2,000,000 per annum. It has been estimated that some 40,000 people are dependent on the industry, and that 7,000 of them are directly engaged in production, either as growers or employees.

Of the total Australian production, it is necessary to export approximately 80 per cent., or roughly 50,000 tons per annum. The export trade is thus of outstanding importance to the Australian grower. Even in the early days of the industry, that is, immediately subsequent to the war, the competition in outside markets by such countries as the United States of America, Persia, Greece, Turkey, &c., was sufficiently strong to impress on the industry the urgent necessity for the use of efficient methods of growing the grapes, of drying, dipping, grading them, &c., and for the rapid improvement of such methods through scientific research. The present Commonwealth Research Station, Merbein, is largely the result of that realization. In fact, for a year or so the Station was financed entirely, and in subsequent years to a very considerable extent, by the industry.

2. Early History of Organization and Finance of Station.

At a large meeting of Mildura and neighbouring district growers which met on 1st December, 1917, the following resolution was unanimously agreed to:—

“That a Committee of practical growers, with the Principal of the High School as Secretary and the agricultural representative as member, be appointed to inquire into the causes and treatment of black spot, and other vine diseases, with power to take such steps as they deem necessary to wipe out these diseases, and to authorize expenditure, if necessary, to the extent of 1s. per ton (dried weight) on the 1918 season vine fruits—such fee to be collected from the packing houses on the 1st of May, 1918, and if not immediately needed, to be held in War Loan Bonds, as a future fighting fund in the interests of the dried fruits industry of Mildura and Merbein districts—and that the Committee take prompt steps to inquire into all available evidence, so that experiments may begin at once.”

The Committee referred to in the resolution was formed immediately, and for some years it was known as the Mildura and District Research Committee. Late in 1920, however, it was replaced by the Vineyards Protection Board, which was a body that was legally constituted under the Mildura Vineyards Protection Act No. 2959 (Victoria) with power to rate vineyards up to 2s. 6d. per acre. The primary objects of the Board were (i) to police the entry of plants and fruit which could possibly introduce additional pests and diseases into the isolated settlement of Mildura, and (ii) to carry out research work.

At its first meeting, the above Research Committee appointed Mr. A. V. Lyon, then of the Mildura High School staff, to act as its investigator. Mr. Lyon has been in charge of the investigations ever since, and is now Officer in Charge of the Commonwealth Research Station, Merbein, where they are centred. The Victorian State Rivers and Water Supply Commission was immediately sympathetic to the objects of the Committee, and provided an area of some 60 acres free of rent for the purpose of the work. It also provided irrigation water free of cost for some years, and subsequently at half rate. Since 1932, all water rates have been remitted. At the time of the formation of the Research Committee, and for several years afterwards, a sum of £200 was also made available as rent from the Mildura High School "College lands."

In the year 1918, the above Committee approached the predecessor of the Council for Scientific and Industrial Research, namely, the Advisory Council of Science and Industry, with a request for financial assistance. As a result, it was eventually arranged that, as from the beginning of the year 1919, the Advisory Council would contribute on the basis of 10s. for every £1 subscribed locally up to a maximum subsidy of £750 per annum. This agreement was conditional among other things on the minimum average amount being subscribed by the vignerons being £1,000 per annum and on the results being made public by the Council so that all the States of the Commonwealth and not only one State might be benefited. The work proceeded on this basis for five years, and in 1924, the immediate predecessor of the Council and the successor of the Advisory Council, namely, the Institute of Science and Industry, published a Bulletin (No. 28) compiled by Mr. Lyon and entitled "Problems of the Viticultural Industry." This publication gave most of the results obtained to that date.

During the years 1925 and 1926, the Vineyards Protection Board received a grant of £750 per annum from the Victorian Department of Agriculture. At that time too it began to derive a return of about £600 per annum from the sale of produce, all of which return was devoted to the experimental work. In 1926, however, realizing that with the growth of additional settlements, protection of one portion alone would be ineffective, and that it was inequitable to rate growers of the Mildura district only, when the work of the Station was of value to a much wider circle, the Board applied for a repeal of the Act under which it was constituted. Accordingly a new district, including all settlements producing dried fruits along the Murray River in the States of New South Wales and Victoria, was proclaimed, and the necessary inspectional work undertaken by the two States concerned.

Having previously assigned all its assets, including planted land, buildings and equipment of the Research Station, to the Council for Scientific and Industrial Research, the Vineyards Protection Board finally ceased to function in 1930 on the repeal of its Act by the Victorian Government.

3. Subsequent Organization and Finance.

In anticipation of the cessation of its activities, the Mildura Vineyards Protection Board suggested in 1927 that the Council for Scientific and Industrial Research should take over the Station. This was arranged shortly after, and since 1927 the Station has been controlled and financed by the Council. The load, however, has been considerably lightened by the previously mentioned co-operation of the Victorian State Rivers and Water Supply Commission, by the Australian Dried Fruits Control Board, which in 1930 agreed to contribute £1,000 per annum for two years, and by the assistance afforded in funds and service by a number of growers' organizations scattered throughout the whole of the irrigation districts along the Murray River.

Subsequent to the taking over of the Station by the Council, it was considered that the work would be helped if the advice and assistance of the Divisions of Soils and of Plant Industry could be made available at all times, and if these bodies assisted in the initiation and conduct of those experiments at the Station which lay in their special fields. Such a condition of affairs has now been brought about through a Committee of Control which has been set up in connexion with the work of the Station, and of which the present personnel is :—

Dr. B. T. Dickson, Chief, Division of Plant Industry.

Professor J. A. Prescott, Chief, Division of Soil Research.

F. K. Watson, Esq., Water Conservation and Irrigation Commission,
Griffith, New South Wales.

In addition, an Advisory Committee, consisting of representatives of the State Rivers and Water Supply Commission, of packers, and of local growers, has been set up in order to secure close co-operation between the Council and the respective bodies, and also in order to maintain local interest in the investigations. The present personnel of this Committee is :—

D. C. Winterbottom, Esq., Mildura Packers Association (*Chairman*).

S. P. Bromfield, Esq., State Rivers and Water Supply Commission,
Victoria.

F. K. Watson, Esq., Water Conservation and Irrigation Commission,
New South Wales.

A. Lever, Esq., Merbein fruitgrowers.

J. A. Lochhead, Esq., Mildura fruitgrowers.

A. E. Cameron, Esq., Red Cliffs fruitgrowers.

A. V. Lyon, Esq., Commonwealth Research Station, Merbein.

Periodically, the Advisory Committee meets a similar body of the Commonwealth Research Station, Griffith, New South Wales, in joint conference at either Merbein or Griffith for discussion of the investigations being carried out at both Stations and to raise any additional problems that may be considered as urgently requiring solution. State and Commonwealth officers engaged on similar work attend these joint meetings when opportunity is afforded to discuss the status and plans of related investigations, and to see the work of the Station at which the meeting is held.

4. Lay-out and Staff of the Station.

(i) *Lay-out*.—The Station is situated in the southern portion of the Merbein settlement, on the Murray Valley highway from Mildura to Adelaide. It is 4 miles from the Merbein township and 9 from Mildura. The land is of relatively low quality, and for this reason was originally excised from the soldier settlement blocks. It is Crown land, vested in Trustees appointed by the State Rivers and Water Supply Commission.

Prior to planting the area, a map of the original vegetation distribution was prepared, and this has served as a useful guide to soil conditions pending a more complete soil survey of the Station. There was a good natural slope for irrigation purposes, and no preliminary contouring or grading was necessary for laying out the plots. No special surface drainage is installed, but underground drainage to the extent of two timbered shafts each 4 feet by 2 feet in section, 60 feet or more deep, and penetrating to the porous layers have been provided. From these shafts, drives have been put out into the porous layers to a distance of 10 feet.

At the present time, and exclusive of the newly-planted salt field, about 16 acres are planted approximately as follows :—

8 acres Sultanas, 6 acres Zante Currants, 1 acre Gordo Blanco, and 1 acre Miscellaneous, including phylloxera resistant stock.

During planting, the necessary provision was made for replications, standard checks, and buffer rows of vines to overcome the overlapping influence of adjacent plots. Irrigation water enters at the north-east corner after being pumped from the river for the whole settlement. Whilst the farm was designed for investigational work, it has been developed as much as possible on commercial lines, and a good annual crop is now obtained.

During the last two years or so, another field of 17 acres has been planted in order to obtain accurate data regarding the salting of irrigation blocks—a problem which has become all too evident throughout closer settlements of the Murray. Before planting this field, it was botanically surveyed in the virgin state, and a survey of the original salt content of the soil was also carried out (see this *Journal*, 4 : 12, 1931). As a result, it was established that the distribution of salt both laterally and vertically was far from uniform.

The older vineyard is now being used for viticultural, irrigation, and drainage studies, while the newer portion is almost wholly reserved for the study of salt distribution in relation to the virgin state, and to changes consequent on irrigation, drainage, and the growth of vines and cover crops.

(ii) *Staff*.—As at present organized, the staff of the Station is as follows :—

(a) *Scientific*—

A. V. Lyon, M.Agr.Sc., Officer in Charge.

J. E. Thomas, B.Sc., B.Agr.Sc., B.V.Sc., Agricultural Officer.

D. V. Walters, B.Agr.Sc., Technical Assistant.

(b) *Other*—

J. E. Giles, General Assistant.

T. Corrie, Farm Foreman.

J. A. Kennedy, Farm Labourer.

Casual employees as required.

As will be seen from Section 6, however, it is hoped to augment this staff somewhat in the near future.

5. Work of the Station.

The main lines of investigations originally laid down in the days of the Mildura District Research Committee are still being followed up to-day, but naturally, as the work has progressed, other avenues of useful work have become apparent and other problems have also become urgent. The programme has thus grown considerably since the original fields were planted.

The present work of the Station may be discussed under the following headings :—

(i) *Fruit Processing*.—The work of the Station on the processing of dried fruits has proceeded for several years. The necessity for it arose through the original unsuitability of the Australian product for overseas markets. The caustic soda dip in former use resulted in dark coloured sultanas and raisins, whereas a light colour, similar to that of the products of the Levant, was favoured on the London market.

The investigation initially consisted of a study of Greek methods of cold dipping in a solution of potassium carbonate to which an olive oil emulsion is added, and the necessary modifications for shaded rack drying as practised in Australia as compared with exposure to the sun on trays, for which the Greek method is devised. A satisfactory procedure was evolved and recommended to growers.

The product from the “cold dip” proved satisfactory, but the slow drying rate, in relation to rack space, was found to be a disadvantage. With an improvement in prices in recent years, additional rack space is being provided by growers, and the present position is that the quantity of fruit cold dipped is steadily increasing, and the product on the whole is giving the best returns. The Australian Dried Fruits Association has recognized this fact, and is making provision to include the procedure for cold dipping in the standard recommendations.

The “mixed dip,” designed to give a colour approaching that of the cold dip, but with a quicker drying rate, is now used for the major portion of the dried fruit in Australia. Over 90 per cent. of the fruit produced in South Australia is so treated. Compared with the cold dip, it is applicable to a greater range of conditions and diversity of seasons. The mixed dip was evolved at the Merbein Station, and as far as is known is used only in Australia. The experimental data on which the recommendations were based have not yet been published, being preceded by a pamphlet describing the preparations and their use. This pamphlet was prepared by Mr. A. V. Lyon and issued by the Australian Dried Fruits Association in 1932. The cold dip has been described in the Council's Pamphlet No. 6, issued in 1928.

(ii) *Irrigation Experiments*.—These are of two types—

- (a) A study of the soil moisture changes occurring at Renmark and Merbein, and the “consumptive” capacity of the soil-plant group on representative soil types.
- (b) A study of the method and frequency of application of irrigation water with respect to soil type. This work is also carried out at several settlements. A report containing suggestions for somewhat modified practices throughout the irrigation settlements has already been published as the Council's Pamphlet No. 26. Throughout these various settlements, the periodicity of irrigation is arranged by local advisory boards who thus have the power of saying when an irrigation will commence in

any district and roughly in what order the individual settlers will be watered. The method of irrigation of a particular block, however, is under the control of the block-holder. It has been established that in the past rather too much water has been applied to blocks, and also that the block-holders' methods of application have been unsatisfactory. Such conditions can often seriously damage the land by water-logging, sometimes associated with salting, resulting in whole or partial unproductivity of affected portions.

(iii) *Salting of Irrigated Soils*.—The work under this heading is mainly carried out in the new salt field already mentioned. It is fundamental and long dated, but it is designed to ascertain the conditions under which "salt" shows in a vineyard irrigated in the usual way, and also to obtain information on which preventative and remedial measures for salted blocks throughout the irrigated settlements as a whole may be based. The work is associated with the methods of irrigation, the rate, quantity, and frequency of application, and agricultural drainage in relation to soil profile.

(iv) *Viticultural Studies*.—Work of this nature has been carried out since the earliest days of the Station, and included an examination of the methods followed in establishing a vineyard in irrigated soils. This was of special importance during the development of the soldier settlements. Viticultural studies now include the following :—

- (a) The methods of pruning so as to permit of a satisfactory quantity of fruit of good quality, and a balance of growth to ensure the potential crop for the following year. This study is carried out in relation to soil type and general environment, and embraces a comparison between potential and actual yield.
- (b) A study of the balance of fruit and annual vegetative growth. This question is being reviewed, as results recently obtained by Winkler in California indicate an advantage in light pruning accompanied by bunch removal, a practice which gives an increase in foliage in relation to the number of bunches, in comparison with present methods by which bunches and foliage are removed proportionally in pruning.
- (c) The extent to which yields may be influenced by shortening the shoots by "tipping" and "topping," practices which have been shown to influence bud development.
- (d) The effect of disbudding in early spring of adventitious shoots on spur-bearing varieties. An influence on the quality of the fruit has been established, and the study has been extended to an investigation of the relation of the size of the bunch to the individual shoot on which it is borne.
- (e) On very old vineyards where yields are unsatisfactory, the rehabilitation or reconditioning of the vines is being studied and the variability of yield noted with a view to determining methods by which yields may be increased and made more uniform.

- (f) A study of some of the seasonal operations affecting the setting of fruit. The practices of "cincturing" and "topping" are known to influence setting, and the effects are being studied in detail. The results of sulphuring at flowering time are also being observed.

(v) *Botanical Studies—Roots and Bud Differentiation.*—A study of the normal feeding habits of the sultana has already been carried out and the results published*. The bud studies form part of a scheme of work in co-operation with the Division of Plant Industry whereby it is hoped to ascertain the relations between growth and fruit bud differentiation in order to be able to carry out manurial and pruning practices conducive to the best yield of best quality fruit. It is fundamental and long dated work. The results obtained to date were published last year† and show that the basal buds are differentiated by about the 12th November, whilst those of the sixteenth node are differentiated by the 11th December, that is, fifteen months and sixteen months respectively before the fruit corresponding to the buds is finally mature.

(vi) *Manurial Experiments.*—Work of this nature is carried out mainly on plots that have been established at Renmark and Red Cliffs. The plots have been laid out on the Latin square basis to determine the relative effects of no manure, superphosphate, ammonium sulphate, and superphosphate plus ammonium sulphate on growth and yield. This field is proving very useful in the development of the technique for yield measurement, which includes a record of the performances of the individual buds on fruiting wood.

6. Extension or Work to Other Districts.

A feature of the Station's work of recent years has been the ever increasing demand for the results of the Station's investigations and for the necessary testing work before they are applied to the local conditions of the other dried fruits settlements. As an example, the case of Woorinen might be quoted. In this district, maturity is from a week to ten days later than Mildura, and troubles thus arise owing to unsatisfactory climatic conditions at the end of the drying period. It is believed that the effects of this lag might be overcome by the adoption of slightly different cultural methods and by different irrigation methods whereby maturity is hastened. Experimental work on the matter, however, is needed, and plans for its initiation are now under consideration.

This work in other districts and the more rapid development of the investigations at the Station itself cannot be financed from the funds which the Council can provide, and the work must perforce wait until the necessary finance is forthcoming. Nevertheless, there is reason to hope that contributions will be forthcoming in the near future, and that it will thus be possible to make the necessary small addition to the present staff.

7. Co-operation with State Departments and Primary Producers' Organizations.

(i) *Processing of Dried Fruits.*—An important feature of all investigations involving recommendations to producers is the standardization of those

* This Journal 5: 88, 1932.

† This Journal 5: 97, 1932.

recommendations. For this phase of the work, the Council has, in co-operation with the other organizations concerned, formed the Interstate Fruit Processing Committee, the personnel of which is as follows :—

- A. V. Lyon, Esq., M.Agr.Sc., Council for Scientific and Industrial Research (*Chairman*).
- W. R. Jewell, Esq., M.Sc., F.I.C., Agricultural Research Chemist, Department of Agriculture, Victoria (*Secretary*).
- Geo. Quinn, Esq., Chief Horticultural Instructor, Department of Agriculture, South Australia.
- C. G. Savage, Esq., Director of Fruit Culture, Department of Agriculture, New South Wales.
- F. de Castella, Esq., Viticulturist, Department of Agriculture, Victoria.

This Committee has arranged for the initiation of urgent investigations, by State and Commonwealth authorities, and for issue of joint recommendations to producers on a Commonwealth basis. The Committee recognizes that standardization of recommendations is a necessary prelude to standardization of the products on an Australian basis, and has already taken the necessary action in regard to dried grapes, apricots, peaches, and prunes.

(ii) *Irrigation Problems*.—A very close co-operation is maintained with the irrigation districts in Victoria, the Merbein Station being represented on the Local Advisory Boards for irrigation. Similar action is being taken in the principal Murray River Settlements in South Australia and New South Wales where the irrigation and agricultural officers of State Departments co-operate in both investigational and advisory work. There is a very general recognition of the importance of proceeding with investigations of irrigation problems, and it is recognized that economy and efficiency in water distribution are accompanied by better annual yields and preservation of the capital value of the land. The basis of co-operation in South Australia may be illustrated by a motion passed in August, 1932, at a special Conference at Berri, convened by the South Australian Director of Lands, when it was resolved—"That it be a recommendation from the Conference that the Council for Scientific and Industrial Research, the Agricultural Department, and the Department of Lands (of South Australia) confer regarding improved methods of irrigation and the establishment of investigational and demonstrational plots on the more difficult soil types of the various irrigation areas."

The suggested action has been taken, and the investigations were commenced on a co-operative basis in January, 1933.

(iii) *Non-Irrigated Vines in South Australia*.—Action to initiate investigations was taken by the State Dried Fruits Board of South Australia, it being recognized that both yield and quality of fruit were unsatisfactory in these areas. Investigational plots have been established, and a supervising Committee appointed by the State Board. The Committee consists of the following members :—

- J. Victorsen, Esq., South Australian Dried Fruit Board.
- W. N. Twiss, Esq., South Australian Dried Fruit Board (*Secretary*).
- A. V. Lyon, Esq., Council for Scientific and Industrial Research.
- Geo. Quinn, Esq., Department of Agriculture, South Australia (*ex officio*).

The investigations are carried out by the Department of Agriculture assisted, as opportunity offers, by members of the staff of the Merbein Station. A very pleasing feature of this movement is the co-operation of the settlers, who have formed local committees to assist in carrying out the investigations and in supplying funds for the work on the plots.

(iv) *The Nyah-Woorinen Research Committee.*—Growers in the settlements of Nyah and Woorinen have been largely responsible for the establishment of this Committee, the personnel of which includes representatives of C.S.I.R., the Victorian Department of Agriculture, the Victorian State Rivers and Water Supply Commission, and the settlers. With the assistance of the Committee, irrigation investigations are carried out conjointly by the Council (C.S.I.R.) and the Victorian Department of Agriculture, and the viticultural investigations by the Council.

(v) *General.*—The four principal co-operative efforts in which the Merbein Station is concerned have been cited above. An important feature is the provision to prevent overlapping of investigations and the opportunity for contact for officers engaged on similar work.

8. Economic Value of the Station's Work.

The assessment of the value of the Station's investigations is difficult owing to changing conditions of markets and world conditions. There is no doubt, however, that it is very considerable and that it represents an acceptable national dividend. An indication of the financial value of the whole co-operative efforts of those concerned may be obtained from the following paragraphs which briefly summarize the more outstanding results that have been obtained :—

- (i) Since the commencement of work twenty years ago, the average yield of dried fruits per acre has doubled.
- (ii) A successful export trade has been established, the quality of the dried fruit being so improved that successful competition with other countries in the principal world's markets is being maintained.
- (iii) The cash value of the improvement in quality of the dried product, in comparison with that obtained by former methods, is obtainable for the transition period. Thus, in 1930, of the total pack of 73,000 tons, over 40,000 tons were processed by improved methods evolved at the Station. Trade returns showed an increased value in competitive markets at the same period, of over £5 per ton, of fruit treated with improved methods as compared with former methods. Thus the improved methods returned in the one year an advance of £200,000 to the industry. Since then, the improvement in quality has been maintained, and the newer methods have extended to additional districts.
- (iv) The annual rateable value of the water supplied in the Mildura district alone is now approximately £100,000 per annum. Decreased costs in supplying this water, accompanied by more efficient production of dried fruits and a decided slackening in the rate of depreciation of the irrigated lands, are features of the operations of recent years.

Further Observations on the Association of Mallee Scrub with Frosts.

By E. S. West,* B.Sc., M.S.

Summary.

Data obtained since the mallee scrub has been cleared on the Murrumbidgee Irrigation Areas confirm the conclusion of a previous report that mallee scrub causes lower temperatures to be experienced on calm, clear nights in and near the scrub, than in open country.

1. Introduction.

At two localities on the Murrumbidgee Irrigation Areas, one in the Yenda district and one in the northern portion of the Lake View district, unusually severe frosts have caused considerable damage from time to time. So serious have been these frosts that at Yenda, plantings of citrus have been replanted to other varieties, while at Lake View the area was abandoned altogether for horticultural purposes, and the few men who had endeavoured to establish orchards there sought farms in more favoured localities.

The proximity of uncleared mallee scrub at both localities suggested the possibility that this may in some way be the cause of the unusual frosts experienced. Observations made by exposing minimum thermometers within the mallee, near the mallee, and some distance from the mallee, showed that consistently, and regardless of the surface contours, the minimum temperatures on calm, clear nights became lower as the mallee scrub was approached. Observations were made on four distinct, widely separated belts of mallee, and on several sides of each belt, with the same results.

These results were summarized in a previous paper,† in which it was concluded that mallee scrub had an important influence in causing severe frosts. Since that time, some of the mallee in which these investigations were carried out has been cleared, and an opportunity was thus afforded of confirming, or otherwise, the conclusions previously drawn, by observing the effect of the removal of the scrub on the minimum temperatures.

2. Field Observations.

After portion of the mallee had been cleared, thermometers were set up in eighteen positions in which minimum temperatures had previously been recorded, sites being selected where the scrub still remained, where it had recently been cleared, and where none of it occurred. It was found that where the mallee still remained, the minimum temperatures were lower than in the open country, but where it had been cleared, the minimum temperatures were higher, relatively, than they had been before the mallee was cleared, and were now similar to those in the originally open country.

* Officer-in-Charge, Commonwealth Research Station, Griffith (N.S.W.).

† This *Journal* 4: 173-177, 1931.

A further confirmation is obtained from the data yielded by minimum thermometers exposed in certain localities throughout the winters of 1930, 1931, and 1932, which were read regularly throughout the winters. The following table summarizes some of the results which were obtained:—

Station.	Remarks.	Mean Minimum Temperatures on Clear Nights. (In deg. Fah.)		
		1930.	1931.	1932.
Research Station ..	10 miles from mallee	30.0	30.0	30.0
Farm 1985 ..	Near mallee, Lake View, mallee cleared 1931-1932	24.5	25.2	27.7
Farm 1494 ..	Near mallee, Yenda, mallee cleared after 1930 readings	26.2	28.6	28.7
Farm 1822 ..	3 miles from mallee, Lake View ..	27.1	27.8	27.5
Farm 1325 ..	2 miles from mallee, Yenda ..	..	27.8	27.5
Farm 1589 ..	3 miles from mallee, Lake View ..	28.9	..	28.3

To obtain the mean minimum temperatures, the mean difference between the minimum temperatures recorded at the station under consideration and at the Research Station was found, and the relative mean minimum temperature then calculated, taking the minimum temperature at the Research Station as 30.0° F. as a standard. Only readings on calm clear nights were used.

3. Discussion of Results.

The relative minimum temperatures of stations, other than those of farms 1985 and 1494, were approximately the same each year. In fact, this was also the case for other thermometer stations from which similar temperature data are available, but which are not included in the above table. Appropriate precautions were taken, of course, to expose the thermometers under reproducible and similar conditions each year.

Farm 1985 is about 20 acres in extent, and during the 1930 winter was completely surrounded by uncleared mallee scrub. Some of this was cleared before the 1931 readings were taken, leaving uncleared mallee scrub on one side of the farm. Before 1932, a further area was cleared, and bush fires killed the rest, leaving only dead timber devoid of leaves. It is seen that the relative minimum temperatures became progressively higher as more of the mallee scrub was cleared. During the 1932 winter, when the scrub that remained had been more or less destroyed by bush fires, so that its influence was probably negligible, the minimum temperatures were similar to those in other localities similarly situated, such as the stations at farms 1822 and 1589, situated at Lake View, and farm 1325, situated at Yenda, which farms are several miles from any scrub.

Mallee scrub existed adjacent to farm 1494 prior to and during the 1930 winter, but was cleared before the 1931 winter. It is seen that in this case, also, the relative minimum temperatures were increased after clearing the mallee scrub, so that they are now similar to those experienced in other similarly situated localities.

The clearing of the scrub had a greater influence on the station at farm 1985 than at farm 1494, and this is what was to be expected, as farm 1494 was adjacent to about 100 acres of scrub only, while in the case of farm 1985, the scrub was a few thousand acres in extent, and, moreover, it completely surrounded the farm.

The standard error of the mean differences between any other thermometer station and that at the Research Station is 0.3 to 0.4, so that the differences observed, due to clearing, being from 7 to 9 times this standard error, are undoubtedly significant.

A large amount of data was collected which showed that these "standard" stations actually represented the conditions of the locality. Thus, for each station for each year, several other thermometers were exposed for several nights in the locality of the "standard" station, so that it is known that these "standard" stations represent the conditions obtaining throughout the localities they represent.

It may also be explained that the minimum temperatures at the Research Station represent average conditions on the Irrigation Areas, as made evident not only by extreme temperature observations, but also by long experience of severity of frost damage. Districts exist on the Areas where the degree of frost is usually less than that experienced at the Research Station, while, as is evident from the figures of the Table, both the Lake View district and the Yenda district, broadly speaking, have slightly more severe frosts than the general average. Besides these generalities, as are always found, small isolated areas in hollows experience more severe frosts than the general average of the locality, while on rises the frost is less severe. The effect of the mallee, both at Yenda and Lake View, was superimposed on these other conditions.

Since the mallee was cleared at Yenda, a definite improvement has occurred with regard to the amount of frost damage experienced. In the case of the Lake View locality, the clearing of the mallee has entirely altered the agricultural outlook of the locality. Prior to the clearing of the mallee, young citrus orchards were almost entirely wiped out with frost two years in succession, and the locality was abandoned for horticultural purposes. Since that time, two young citrus orchards have been established, and withstood the severe winter of 1932, which, from the point of view of frost, was as severe, if not more severe, than any other winter experienced since records have been taken at Griffith; and the locality is now considered suitable for horticultural purposes.

Apart from the evidence of the temperature readings, the changed conditions at Northern Lake View since the clearing of the mallee are quite apparent to those who are familiar with the locality. The severity of visible frosts, amount of injury to susceptible crops, freezing of taps, and other familiar manifestations of severe frosts, all tended to show that the locality was unusually subject to frost, but the conditions do not now appear abnormal.

A Possible Biological Control of the Clover Springtail or Lucerne Flea (*Sminthurus viridis* L.) in Western Australia.

By H. Womersley, F.E.S., A.L.S.

Mr. Womersley was appointed to the staff of the Council early in 1930. Prior to that, he had specialized on groups of minute insects in England, and before coming to Australia he spent some months as an officer of the Council examining—at the British Museum and elsewhere—those families of insects of which a knowledge would be helpful in connexion with work on the clover springtail and the red-legged earth mite which it was proposed he should investigate in Western Australia. After spending a short time in South Africa, in the hope of obtaining likely parasites, he reached Perth late in 1930, and was then afforded valuable assistance in the form of laboratory accommodation, &c., by the Western Australian Department of Agriculture and by the University of Western Australia. He resigned at the end of 1932 to take up the position of Entomologist to the Public Library, Museum, and Art Gallery of South Australia. The Board of Governors of that organization has agreed to the Council's suggestion that he be permitted to continue his work on the Bdellid mites of Australia. He will undertake work on this group as part of his routine duties at the museum.—[Ed.]

Summary.

1. In certain areas of Western Australia, a species of Bdellid mite, *Biscius lapidarius* Kramer, possibly an introduction from Europe, has made its appearance in paddocks infested with the clover springtail (lucerne flea), *Sminthurus viridis* L.
2. Field observations extending over two years have shown that this mite is an active predator on *Sminthurus*, and reduces the population to negligible proportions within a comparatively short time.
3. Transportation to other areas has been partially successful and the areas have been cleared of *Sminthurus*.
4. As the breeding up of the mite in large numbers does not seem feasible, specimens can best be transferred from localities where active attack is proceeding.
5. The species, its immature stages, and partial life-history, are described and figured.

1. Introduction.

The paper that follows is an account of researches carried out in Western Australia during 1930-32 on the possibility of finding some natural agency for the control of the clover springtail or "lucerne flea" (*Sminthurus viridis* L.). The author was working under the auspices of the Commonwealth Council for Scientific and Industrial Research as an officer of the Division of Economic Entomology, and in conjunction with Mr. L. J. Newman, Government Entomologist of Western Australia. At the outset, therefore, he would like to express his appreciation of the valuable help that Mr. Newman, by his intimate knowledge of the pastoral conditions of the country, has been able to render, and especially also to thank Dr. R. J. Tillyard, Chief of the Division of Economic Entomology, at whose instigation he was engaged upon this problem, for much encouragement and advice.

The species of *Collembola* dealt with in this paper is perhaps one of the most important and difficult insect pests with which the State Entomologists of Australia have to contend. This is largely owing to the immense numbers in which it occurs in the paddocks, especially in those which have been laid down with subterranean clover.

According to available records it has been known in South Australia since 1884, and in Western Australia since 1914. It is largely influenced by the rainfall, occurring only where this exceeds 16 inches per annum. Further, because of the habit of soil ingestion by the newly hatched nymphs and also by the adult females prior to oviposition, it is rarely found inhabiting sandy country.

In addition to this species, several other species of the order are now known to occur in various parts of Australia in such numbers as to constitute potential pests at least. Some of these are probably introductions, but others are indigenous and have undoubtedly increased in numbers as more and more of the country has been brought under pasturage. From the aspect of biological control, however, we can consider all these species at the same time as *S. viridis*.

2. Review of Biotic Balance in *Collembola*.

Economically, because of the large acreages usually infested and the astounding numbers of *Collembola* present—rough estimates have given at least 60,000,000 per acre—cultural and spraying methods of control, while partially successful, are rather of the nature of palliatives, and are in any case costly. On the other hand, the possibility of biological control is reduced by the fact that—in spite of intensive search—parasites of *Collembola*, either of the eggs or adults, are quite unknown. The only hope of permanent control would seem, therefore, to lie in the discovery of suitable predators.

Many insects and spiders are known which are, to some extent, devourers of *Collembola*. In 1927, Holdaway recorded the Staphylinid beetle *Paederus singulatus* MacL. and an ant, *Pheidole ampla* For. as attacking *Sminthurus viridis* L., while in 1932 MacLagan listed two species of Coccinellidae, 7 of Staphylinidae, 1 Carabid, and 1 Telephorid among the Coleoptera, 1 Anthocorid, and 1 Capsid in the Hemiptera, and also the common European earwig *Forficula auricularia*, as more or less efficient predators. The same author also gave a list of eleven species of spiders as active feeders on *Sminthurus*.

Outside of these two groups, there is no evidence of *Collembola* being attacked by any of the Arthropoda except a statement in Lubbock's "Monograph on the *Collembola* and *Thysanura*," in which, speaking of *Sminthurus viridis* L., he says "It is sometimes attacked by a small red mite." This is, of course, a very vague statement, but, having worked at the Acarina for some years, the writer is of the opinion that the mite in question was probably the larval form of a species of Erythraeidae or Trombididae, the young of which are well known to attach themselves to, and feed upon, a large variety of insects.

In considering MacLagan's work, it must first be noted that he has assessed the value of the predators listed solely on the results of laboratory tests in small vials. In appraising the value of such predators in the field, too much importance must not be attached to results so obtained. His minimum value for what he termed a "good predator" was 1.4 *Sminthurus* eaten per day for not fewer than 35 days in

captivity. The maximum figure for this class was 6.0 for *F. auricularia*. This insect, however, as MacLagan himself pointed out, cannot be considered as a possible control, as it is liable to become a pest itself. For what he termed a "fairly good predator," he obtained a value of 7.7—for the beetle *Philonthus laminatus* Creutz—on the basis of a consumption of not fewer than 60 eaten during captivity irrespective of time. By his original criterion, and leaving out the case of *F. auricularia*, we find a maximum value of 5.0 for the Capsid bug, *Lygus pratensis*, and for the total listed, an average of only 2.8. With the spiders, the results are much the same, the maximum value being 2.4 for a species of *Erigone*, with an average of 1.6 for all species.

From the point of view of biological control, it can hardly be seriously contended that values such as these, even if borne out by field observations, offer any prospect of reducing the population of *Sminthurus* in such heavily infested areas as occur in Australia. From the writer's observations in England and in Australia, there is little evidence of effective control by any of the insects or spiders mentioned by MacLagan. Further, his data are not supported by any evidence of relative predator and *Sminthurus* populations. One must have such information, if only from general field observations, before it can be said that a certain predator exerts a control. In England, the *Sminthurus* population is only a fraction of that occurring in Western Australia, and, as in the former country it is scarcely considered to be a pest, it must be concluded that a biotic balance has probably been reached there.

3. Position in Western Australia.

In the study of this problem in Western Australia, it was soon realized that, almost everywhere where the pest occurred, the population was so dense as to preclude the presence of any satisfactory biological control. Even in such localities, however, many predators, such as those listed by MacLagan, were to be found in large numbers. Especially so were various spiders, but even these did not show any sign of control of the *Sminthurids*. In surveying the extent of the pest, it was obvious that the only chance of finding a suitable agent of biological control must lie in localities where, for some reason or other, the pest had died out or showed signs of doing so.

(i) *Discovery of a Predator*.—Early in May, 1931, observations were made in a paddock at Waroona which was stated to have been badly infested in previous years, but which was then scarcely affected. On examination, it was found that very few *Sminthurus* were present, but that large numbers of a small red mite belonging to the family Bdellidae (snout mites) could be obtained. Further, these mites were observed to be actively feeding upon the Collembola.

(ii) *Identification of the Predator*.—This mite is a species of Bdellidae and was provisionally identified as *Biscirus lapidarius* Kramer, which is a species well known from Europe. This identification was later confirmed by Dr. Sig Thor, the eminent authority of this group of Bdellidae. The actual recognition of the various species of Bdellidae is a very difficult and technical matter; but, in a subsequent paper, the writer proposes to give details of all species known to occur in Australia, together with keys for their separation. A full description of *B. lapidarius* in its various stages will be found in the Appendix (page 89).

4. Field Observations.

(i) *At Waroona*.—As already mentioned, the predatory mite was first observed at Waroona about 70 miles south of Perth, in May, 1931. According to information obtained from the owner, the paddock in which it was first found had been very badly infested with *Sminthurus* in previous years, but was practically free at the time of advice. The author was able to confirm its freedom at the time of his visit. It was, however, noticed that the paddock also contained a large number of Bdellid mites, some of which were actually feeding upon *Sminthurus*. It was therefore decided to keep this paddock under continuous observation, while specimens of the mite were taken back to Perth for identification and further study. In the meantime a very full inspection of the surrounding country was made and, although many paddocks were found to be very badly attacked by *Sminthurus*, in none of them were any Bdellids found.

On 12th May the paddock was again visited, the weather being very cold and showery. This time, very few *Sminthurus* were to be found, but the mites could be obtained in numbers by searching at the roots of the clovers. Seventeen days later, *Sminthurus* was practically non-existent, although the mites were still plentiful. On this visit, the adjoining paddock was examined and found to be badly attacked by *S. viridis*, but no mites could be found.

On 10th July both of these paddocks were found to be practically free of *Sminthurus* and to contain small numbers of Bdellids. On this occasion, the next paddock again (the third), previously heavily infested by *Sminthurus*, was found to have been invaded by the mite, although no visible diminution in the *Sminthurus* population could be noticed. The mites were also found to have reached the corner of the fourth paddock.

On 7th August the density of the pest in the third paddock was measurably reduced, and the Bdellids had advanced some distance further into the fourth paddock.

On 25th September the mite was still progressing, although more slowly, probably due to the approach of the dry season.

In the following season, these paddocks were first visited on 27th April, when the conditions in the first three were found to be as at the close of the previous season, that is, the Bdellids in fair numbers but *Sminthurus* few. In the fourth paddock, the mite had spread further and there was a very definite line of attack, in which the Bdellids were most abundant. In front of this line no mites were to be found, while the *Sminthurus* population was very heavy. Behind it, the *Sminthurus* had been considerably reduced.

By 3rd June the ground had been practically cleared of the pest as far as about half way across the fourth paddock. A last visit was made on 4th November, when, with the exception of about the last quarter of the fourth paddock, the *Sminthurus* population was no longer of economic importance. During the period of observation, the total area cleared in this locality was approximately 65 acres.

(ii) *At Denmark*.—Late in September, 1931, it was found that the same species of mite had appeared in a badly-infested paddock at Denmark. This particular paddock had been inspected in the previous year, but no sign of any control could then be discovered.

By 21st October this paddock was well populated with *Biscirus*, and the numbers of *Sminthurus* had considerably declined. The crop was, however, being cut and stacked as ensilage some distance away. At the foot of the stack, it was found that the Bdellids were becoming concentrated in large numbers.

On 5th July, 1932, when this paddock was again examined, it was found practically free of *Sminthurus*, but by close examination, a few mites were discovered at the clover roots. On inquiry, it was ascertained that the ensilage had been carted since the last visit to a spot about half a mile away and adjoining another heavily infested paddock. During the previous year, this had also been found free of any Bdellid or other control. On this latter occasion, however, it was found that the mites had reached it, evidently from the ensilage placed close by, for they were in large numbers in the corner nearest to it. There was, however, no apparent reduction in the *Sminthurus* population, but no fewer than 20-30 Bdellids could be taken in one sweep of the net.

These paddocks were again visited, in company with Dr. R. J. Tillyard, on 28th September, 1932, when the first was found to be still free of *Sminthurus*, while in the second the Bdellids had spread considerably, both within the paddock and to surrounding areas. The numbers of *Sminthurus* were also being very definitely reduced.

(iii) *At Other Places.*—In several places, notably Burekup and Cannington, similar conditions have been found to exist, and from all such places the farmers report the pest as now being of no importance. Wherever the *Sminthurus* population is found to be very large or on the increase, no Bdellids are present, except odd specimens of species other than *B. lapidarius*.

5. Attempts at Spreading Predator.

Owing to the difficulties attending the breeding up of these predatory mites in large numbers, attention was concentrated on spreading in the field. Specimens were best and most easily collected in sufficient numbers by examining the bits of curly bark that had fallen from the trees in the paddocks. These form ideal sheltering places, and the mites can generally be found under them in large numbers. Local spreading of the creatures will probably be accomplished best by transferring these pieces of bark, with the mites attached to them, where required. Although transportation over long distances has not yet been attempted, the scrapings from the base of an ensilage stack are suggested as a suitable medium.

Late in the season of 1931, about a dozen specimens of *B. lapidarius* from Waroona were liberated in the paddock adjoining the Insectary at Perth. No *S. viridis* were present in this paddock, but it was heavily populated with another species, *Katianna ornata* Womersley. By the beginning of the next season, the mites had increased tremendously and could be collected in hundreds. At the same time, the *Katianna* had decreased and had actually become scarce. Later, the mites themselves, as their food supply became scanty, also decreased within the paddock, but they were found to have migrated to surrounding areas.

Three attempts were made to introduce the Bdellid into a badly infested paddock at Guildford. The first two attempts were apparently unsuccessful but the third, made towards the end of the 1932 season,

was more promising. A month or two after liberation, out of 50 specimens liberated no fewer than 25 were recovered, although no reduction of the *Sminthurus* population was then apparent. The success or otherwise of this experiment will be assessable during the next season.

Introductions were also made at Muresk Agricultural College and at the State Farm at Denmark. All these introductions were made on locations where previous search had failed to show the presence of any Bdellids. This next season should show the results of these experiments.

6. Biology of *Biscirus lapidarius*.

Time has not permitted a very full study of this mite to be made, but the following details of its life-history have been determined.

The eggs are laid on the ground or on the decayed plant fibres lying on the ground. Owing to their coloration and small size, they are very difficult to find in the field. The duration of the egg stage has not been ascertained. It is probable that aestivation takes place.

The larval stage is probably a very short one, for only rarely does one find larvae in the field.

An interesting feature of this mite is that at certain periods it exhibits a partial gregariousness, specimens of all sizes collecting together under any bits of bark or similar material lying about. Frequently, they are to be found under the webs of spiders or Psocids. During this phase, they lie dormant, either preceding, or after passing through, an ecdysis. The period of dormancy may last for several days. The resting mites are rather lighter in colour, as compared with the active ones, and their legs and palpi are entirely white, in marked contrast to the body colour.

The adults are voracious feeders on various small Collembola, but show a very decided preference for *Sminthurus viridis*. They have also been observed to attack Psocids and other small insects. The prey is stabbed by the mite with its mandibles, generally in the neck or ventral region. In attack, it has been noted that the mandibles work alternately in the process of piercing the victim. Once the mandibles have been inserted, the victim is sucked dry.

Preference is shown for the nymphs of *Sminthurus*, although adults are also largely eaten. The mite does not, however, seem to be able to impale the adults quite as successfully as it does the nymphs, probably because of their greater agility.

The nymphs are easily captured, and in preliminary experiments it has been found that a single *Biscirus* devoured 18 nymphs in 24 hours on three successive days. This was the total number of nymphs available each day, but without doubt had more been supplied they would have been devoured.

7. Conclusion.

In concluding this preliminary account, it may be remarked that this is the first example of the use of any member of the Acarina for biological control. Acarina, and arachnids also, providing suitable species can be found, possess a great advantage over the majority of insect

predators, in that feeding takes place throughout their life, whereas other insect predators usually have a pupal or other resting stage. On the other hand, they are generally anything but specific in their food requirements. Species suitable for biological control, if not specific in their food, should be largely so, and be capable of feeding upon other material only during times of shortage of their normal diet. This will permit the retention of a nucleus should a recrudescence of a pest occur, after it has once been cleaned up. The species *Biscirus lapidarius* appears to meet these requirements. On occasions it has been seen to tackle various small Collembola as well as Psocids, which are always to be found in the paddocks.

In Western Australia, many other species of Bdellidae are now known to occur; all of these are predatory and have been observed to attack *Sminthurus* and other Collembola. Nowhere, however, have they been found in the numbers sufficient to suggest that they are material controls. Nevertheless, it is possible that they may multiply sufficiently under suitable conditions. The possibility of biological control, not only by this group but also by other groups of predatory Acarina, might thus well repay careful study.

8. Literature Cited.

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Appendix.

Description of the Adults and Early Stages of Biscirus lapidarius Kramer.

(i) Egg State. (Fig. 12.)

The eggs are small, slightly elliptical, of a brownish colour, and covered with long, somewhat gelatinous, and clavate or spathulate spines. In general they are similar to those figured by Trägårdh for another species, *Molgus littoralis*. They measure $250\ \mu$ by $200\ \mu$.

(ii) Larval Stage. (Figs. 8-11.)

This stage has not been previously described for this species of *Biscirus*. Probably the reason is that the duration of the larval stage is very short. On several occasions, however, the writer has met with the larvae and the following description can be given:—

Length $420\ \mu$. Colour as in adults but a little lighter. Rostrum $100\ \mu$ long, with only 2 pairs of ventral hairs. Mandibles $100\ \mu$ long with two long hairs on each as in the adults. Three pairs of short, thick legs (Fig. 8); from a comparison of the positions of the legs, it would appear that the third pair of the adult is interpolated between the second and third pairs of the larva. Palpi short, $140\ \mu$, ratio of lengths of segments II : III : IV : V = 50 : 17 : 17 : 48, hairs on these segments 1 : 1 : 3 : 7 respectively, apical setae of fifth segment $67\ \mu$ long and as in adults. Body setae differing from the adults only, in that the second row from the front has 2 instead of 4. Eyes 2 on each side, placed on a level with the base of the second pair of legs.

(iii) *Nymphal Stage.*

Except for the absence of the genital organs, the nymphs exhibit no essential difference from the adults.

(iv) *Adult Male and Female* (Figs. 1-7).

As the Australian material agrees entirely with the descriptions given by Dr Sig Thor, his description is translated here.

"Form, colour, and cuticle as usual. Rostrum about $30\ \mu$ long; ventrally with 6 pairs of hairs. Mandibles with 2 long, well developed hairs; the distal hair quite in the middle ($156\ \mu$ from the distal end of a $345\ \mu$ mandible), the proximal $110\ \mu$ from the distal hair; length of distal hair $120\ \mu$, proximal $108\ \mu$. The proportions of the segments of a $435\ \mu$ palp = I : II : III : IV : V = $24\ \mu$: $180\ \mu$: $43\ \mu$: $48\ \mu$: $154\ \mu$. The second segment has 5 hairs, the fifth 8-10; the lengths of the apical setae are $125-170\ \mu$. The dorsal organ on the thorax is very similar to that of *Biscirus intermedius* Sig Thor., but sometimes the front chitinous structure is absent, occasionally both; the fine subcutaneous line is generally very distinct; the 4 (2 pairs) sensory hairs with large basal pores are slightly longer. On the hind edge of the cephalothorax, on the line of separation from the abdomen, are 4 short stiff setae. The fine striations of the cuticle are sometimes circular, sometimes zig-zag and usually transverse. Legs thick with normal hairs. Length of animal $1100-1700\ \mu$, breadth $600-800\ \mu$."

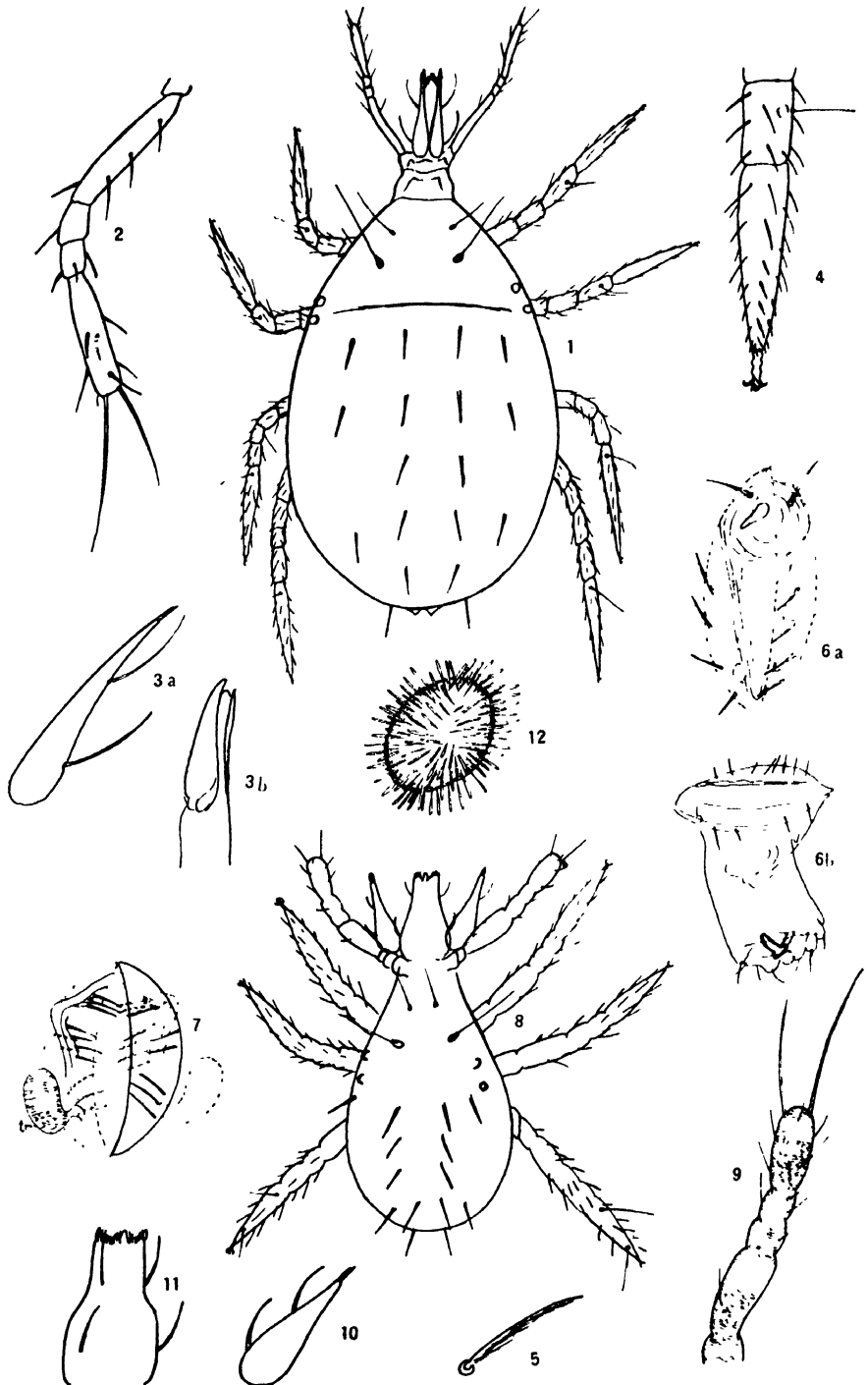
No particulars have been given previously of the differences* in the sexes. In the adult stage, however, it is not difficult to distinguish them by the genital organs. In general, these organs lie below and between a pair of lips situated a little behind the last pair of coxae. Beneath each lip can be faintly seen three more or less circular discs, which in our species are smaller than those figured by Oudemans for *Molgus*. In the female, at the anterior end of the opening, is an exsertile organ of the nature of an ovipositor (Fig. 6a-b). In *B. lapidarius*, this organ is furnished apically with a short chitinous rod. The writer has not been able to detect this rod in any other species which he has examined, nor as far as he is aware has it been figured. It is always easy to see, in *B. lapidarius*, whether the ovipositor be exserted or not.

In the male sex, the most striking feature of the genital organ is a pair of posterior, recurved, granular, lobed organs which Oudemans terms "titillating organs" (Fig. 7).

EXPLANATION OF PLATE.

Biscirus lapidarius Kramer.

- FIG. 1.—Dorsal view of entire animal.
 FIG. 2.—Palp of adult.
 FIG. 3.—Mandible of adult (a), entire (b) jaws.
 FIG. 4.—Tibia and tarsus of adult.
 FIG. 5.—A dorsal seta of adult.
 FIG. 6.—Female genital organ, (a) ovipositor withdrawn, (b) exserted.
 FIG. 7.—Male genital organ, t = titillating organ.
 FIG. 8.—Larva, dorsal view.
 FIG. 9.—Palp of larva.
 FIG. 10.—Mandible of larva.
 FIG. 11.—Rostrum of larva, ventral view.
 FIG. 12.—Egg.



The Active Immunization of Sheep against Infectious Enterotoxaemia (Braxy-like Disease) by means of *B. ovitoxicus* Anaculture.

By H. W. Bennetts, D.V.Sc.

The work described in the report that follows has been carried out under a co-operative arrangement entered into by the Council and the Western Australian Department of Agriculture. Briefly, this arrangement was that the Department seconded its Veterinary Pathologist, Dr. H. W. Bennetts, to the Council, and in addition made various laboratory and other facilities available for the investigations. As a result of the work, Dr. Bennetts has been able to show that enterotoxaemia, or the so-called braxy-like disease of sheep in Western Australia, is due to an organism which he has termed *Bacillus ovitoxicus*. Many of the results to date have been published in the Council's Bulletin 57 issued last year. At that time, indications had been obtained that vaccination would probably be a satisfactory way of controlling the disease in certain cases. The report that follows is confirmatory of those indications.—ED.

Summary.

(i) Sheep may be actively immunized against enterotoxaemia by means of *B. ovitoxicus* anaculture. Two inoculations with three weeks' interval are recommended.

During the 1931 and 1932 seasons, the mortality rate in controlled flocks was reduced by 85 per cent. as a result of inoculation.

(ii) A small experiment indicated that lambs fattened on shed peas during the summer months can be satisfactorily immunized by this method.

(iii) Lamb dysentery bacillus anaculture did not immunize guinea pigs against *B. ovitoxicus* toxin, although a response was obtained with *B. ovitoxicus* anaculture.

(iv) *B. ovitoxicus* "alum toxoid," tested on guinea pigs, did not possess any greater antigenic efficiency than *B. ovitoxicus* anaculture.

1. Introduction.

In a previous communication (Bennetts (1)), we have given a full account of the investigation of the etiology of infectious enterotoxaemia (braxy-like disease of sheep in Western Australia) as well as the result of prophylaxis with formalized antigens of the causal organism *B. ovitoxicus*. This preliminary laboratory and field work with anaculture, during 1929 and 1930, gave encouraging results.

The purpose of this article is to record the results obtained in the field, with anaculture, since the publication of this previous report, and to discuss experiments carried out in the laboratory with other types of antigens, including one prepared with the lamb dysentery bacillus, which was tried for reasons indicated.

2. Preparation of Vaccine—*B. ovitoxicus* Anaculture.

This has already been given in detail, and is briefly as follows :—

Bottles containing "horse muscle broth" with about 2 per cent. of meat are inoculated with breast muscle obtained aseptically from pigeons dying as a result of intramuscular inoculation with cultures of *B. ovitoxicus*. Glucose to a 0.1 per cent. concentration is then added and cultures are incubated at 37° C. Originally, a 24-hour period was

used, but it having been demonstrated that more toxic cultures were obtained with longer incubation, a 48-hour period was substituted for vaccines prepared for the 1932 season and subsequently.

The resultant cultures are filtered through muslin to remove meat particles, and 0.5 to 0.7 per cent. formalin is added (the toxin obtained from 48-hour old cultures is somewhat more refractory to the action of formalin and the higher concentration seems necessary). The formalized culture is incubated until a 10 cc. amount is no longer lethal to a guinea pig on intramuscular inoculation. This usually requires about fourteen days. The vaccine is then ready for use. Prior to the addition of formalin, a small amount of culture is removed for titration of toxin content.

During 1931 and 1932, vaccination has been carried out by veterinary officers of the Western Australian Department of Agriculture, and the previous routine of two inoculations at an interval of three weeks has been followed.

3. Field Results in 1931 Season.

From January to August, 1931, a total of 9,679 sheep on 21 properties were inoculated with *B. ovis* anaculture prepared in the Perth laboratory. Throughout, only half of the various mobs were inoculated and branded distinctively, an approximately equal number of un-inoculated animals being run with them as controls. The dose used was 5 cc. followed by 10 cc., both inoculations being given subcutaneously. Young animals received correspondingly smaller doses of 2.5 cc. and 5 cc. No ill effects were noted except lameness, which frequently persisted for two or three days after inoculation. In two flocks, sheep were lame for more than a week. In some cases, on the occasion of the second inoculation, some of the sheep were seen to have a small indurated area at the site of the first inoculation. This appears to be a reaction to the dead bacteria injected, and may persist for several months.

As on previous occasions, the results were somewhat marred by the erratic incidence of the disease. Mortality due to enterotoxaemia occurred in only eight of the flocks where inoculation had been carried out, although the disease had recently occurred on all properties. Further, in these eight flocks, the death rate, with the one exception of 10.9 per cent., was low. The results are tabulated below.

(a) VACCINE PREPARED FROM R2, AND M.R. STRAINS.

Owner.	Controls.			Vaccinated.		
	No. of Sheep.	Deaths.	Percentage of Deaths.	No. of Sheep.	Deaths.	Percentage of Deaths.
I.F. ..	286	12	4.2	286	0	0
S.B.R. ..	1,210	13	1.07	1,360	0	0
M. ..	3,100	117	3.77	1,867	17	0.91
W. ..	315	3	0.95	285	0	0
S. ..	143	2	1.4	143	0	0
W.B. ..	664	4	0.6	597	5	0.84
Whole Experiment ..	5,718	151	2.64	4,538	22	0.48

As a result of inoculation, there was a lowering of the mortality rate from 2.64 per 100 to 0.48 per 100 ; in other words, the mortality rate was reduced to only 18 per cent. of its former value.

Owner M. reported that the inoculated section of his flock had undoubtedly "done better" than the controls, and that the wool and progeny were also better. These claims were confirmed by personal inspection, but this apparent effect of vaccination has not been noted in any of the other flocks. Property M. is very highly improved, and the conditions obtaining are unusually favorable to the incidence of the disease. Following heavy losses in 1918 and 1919, the mortality rate declined, but the flock has never acquired the degree of natural immunity which is almost generally experienced, and for a number of years the average annual death rate from enterotoxaemia has been approximately 5 per cent. Field observations on this and on other properties suggest that a percentage of the flock develop mild attacks of the disease, which detrimentally affect the general health of the animals, although not giving rise to very definite symptoms. On a property such as M's, where conditions are so favorable to incidence, and where the disease has been enzootic for a long period, one would expect a rather large percentage of these cases. The beneficial effect of the vaccine, apart from its preventing mortality, may be due to the increased resistance following its use.

(b) VACCINE PREPARED FROM T2 STRAIN.

Owner.	Controls.			Vaccinated.		
	No. of Sheep.	Deaths.	Percentage of Deaths.	No. of Sheep.	Deaths.	Percentage of Deaths.
M.B. ..	513	5	0.98	487	3	0.62
F. ..	193	21	10.88	186	12	6.45
Whole Experiment ..	706	26	3.68	673	15	2.23

The results obtained with vaccine made from the T2 strain are thus in no way comparable with those obtained with the R2 and M.R. strains. This was not entirely unexpected, as on titration of cultures from which this vaccine was made, it was found that the toxin content was comparatively low, the minimum lethal dose of filtrate for a mouse on intramuscular inoculation being over 0.3 cc. as compared with a minimum lethal dose of 0.1 cc. or lower with batches made from R2 and M.R. strains. Subsequent laboratory experiments also indicate that the T2 strain was of low antigenic value, and it was not used further for vaccine production.

4. Field Results in 1932 Season.

The results obtained in the 1931 season, confirming those of the previous year, have shown that *B. ovis* culture is an efficient immunizing agent. In response to numerous inquiries from stock owners, particularly those with stud flocks, it was decided to extend the vaccination work, at the same time making a charge to cover the cost of the vaccine. As it was

impossible for the Perth laboratory to meet the increasing demand, the Commonwealth Serum Laboratory was requested to supply 100 litres of vaccine for use during 1932, and agreed to do so at a cost of 1½d. for each 10 cc. Twenty-two litres were subsequently made in Perth to supplement the Commonwealth supply.

The method of preparation of vaccine used in 1932 was somewhat modified. The cultures were incubated for 48 hours instead of 24, and they were prepared from two tried strains (M.R. and R1) of *B. ovis*. Vaccines previously used had been monovalent. For the sake of convenience, the Serum Laboratories substituted "V.F." broth for "horse-meat broth" as culture medium.

The doses of vaccine were reduced from 5 cc. and 10 cc. to 3 cc. and 7 cc. for adult sheep, and 2 cc. and 5 cc. for young sheep. It was considered that these amounts of vaccine made from the more toxic cultures would be equally effective. By reducing the dose, the cost of inoculation could also be made more reasonable.

It was found impossible to maintain the system of vaccinating only half of the flock, so that, with two exceptions, no controls were left. In most instances, large numbers of the flock were left un-inoculated, these animals being passed over because they were considered not likely to contract the disease on account of their age or condition. In some cases, only small stud mobs were inoculated. These un-inoculated sheep could not therefore be considered as controls, particularly as they were not generally run with the inoculated section of the flock.

From February to August, 1932, a total of 16,589 sheep were inoculated on 26 separate properties in the Great Southern, Midland, and Eastern districts, at a cost of 1½d. per sheep. The two inoculations were completed, in almost all instances, at least three or four weeks prior to lambing (May-July). The sheep owners were supplied with printed forms, similar to those in use for necrotic hepatitis in Victoria, for the purpose of recording full particulars of deaths occurring in their flocks each month.

There were no ill effects following inoculation with the exception of the lameness already referred to. On one property where the disease chiefly affects lambs (8-12 weeks), we inoculated 288 lambs, many of which were only 2-3 weeks old at the time of the first inoculation. Doses of 1 cc. and 2 cc. were given. No after effects at all were noted, and no deaths due to entero-toxaemia have occurred.

The results obtained for the 1932 season were again very satisfactory, although mortality occurred on 8 of the 26 properties where inoculation had been carried out (viz., S.B.R., M., W.B.—Cf. 1931 and A.R., C.O., M. & B., V. and H.).

Out of a total of 7,743 sheep inoculated on these properties, there were 30 deaths from entero-toxaemia=0.39 per cent. In 6,795 un-inoculated sheep on these same properties, there were 93 deaths=1.37 per cent. (In addition, there were 74 deaths among the new season's lambs.) As previously pointed out, these un-inoculated sheep were not controls, but were generally composed of sections of the flock which were regarded as being less susceptible to the disease.

The results of a controlled experiment on two properties are tabulated in the following table :—

Owner.	Controls.			Vaccinated.		
	No. of Sheep.	Deaths.	Percentage of Deaths.	No. of Sheep.	Deaths.	Percentage of Deaths.
W.B. ..	696	26	3.74	626	5	0.8
V. ..	413	15	3.63	287	0	0
Whole Experiment ..	1,109	41	3.61	913	5	0.55

The results of this experiment are surprisingly similar to those obtained in the previous season, inoculation again lowering the mortality rate to approximately 15 per cent. of its former value.

Monthly records of mortality on the eight properties where the disease made its appearance did not indicate any falling off in the degree of immunity over the seven months' period from the last inoculation in March until the end of the season in October.

From an experimental point of view, it is unfortunate that throughout both seasons' work the incidence of the disease has been low on all properties where vaccination has been carried out. It is notable that since 1927-28 the annual incidence of the disease has generally greatly decreased in the older settled districts. The probable reason for this has been discussed elsewhere. However, even in these areas, heavy losses are still experienced from time to time, particularly on the more highly improved properties. Prophylactic immunization is to be advocated in these special cases and for stud stock generally. The severe enzootics experienced in 1925-1927 may recur, particularly in the newer agricultural districts. Notwithstanding the decreased incidence, the demand for vaccination is still increasing.

5. The Immunization of Lambs Fattening on Peas.

In Western Australia, it is a not uncommon practice to carry June-July lambs through to fatten during the summer months on crops of shed field peas, marketing up till the beginning of April. Scouring frequently results, and a percentage of the animals die suddenly from a condition which the writer has shown to be entero-toxaemia. The owner of a property on which these investigations were carried out had for many years averaged a 5 per cent. mortality in a flock of 500-600 lambs.

In January, 1932, we inoculated 503 of his lambs, consisting of 47 Merino and 456 Shropshire and Suffolk crossbreds. The inoculation was done with anaculture 2 cc. followed by 5 cc. Ninety-five crossbred lambs were left as controls, and of these 3.15 per cent. died of entero-toxaemia. None of the inoculated succumbed. There were originally 50 of the Merino lambs, and 3 of these had died from the disease prior to the time of inoculation. The owner reported that a feature of the lambs this year was the freedom from scouring, only a few showing it. He also indicated that it was remarkable how few of the un-inoculated lambs were suitable for inclusion in the first draught for market.

This experiment indicates that lambs fattening on peas can be successfully immunized against entero-toxaemia. Inoculation can be carried out without fear of checking the lambs.

6. Laboratory Experiments with Modified Vaccines.

Although the results attending the use of formalized culture as a prophylactic vaccine had been very satisfactory, we hoped to be able to produce a better product, or rather one which would give equally good results with a smaller dosage. This investigation proceeded along two main lines:—

- (i) *Alum toxoid*.—The use of tapioca, calcium chloride, and other materials injected with vaccines has been recommended as a means of increasing antigenic effect. The increased immunological response obtained is considered to result from prevention of rapid absorption and excretion of the antigen. Glenny and others (4) have used toxoid (anatoxin) precipitated with potash alum, and have obtained increased antigenic efficiency which they have shown to be due to slow absorption and elimination of the insoluble product "alum-toxoid". Following similar lines, attempts were made to immunize guinea pigs and to hyper-immunize rabbits with *B. ovis* alum toxoid.

The results of a series of experiments indicated that, in laboratory animals, the response to these products was not superior to that obtained with anaculture. It was concluded that the dead bacteria in the vaccine promoted sufficient local reaction (Cf. sheep) to prevent the too rapid absorption and elimination of the anatoxin, as well as, the bacteria, themselves possibly acting as antigens.

- (ii) *Lamb dysentery bacillus anaculture*.—In order to make it clear why the lamb dysentery bacillus should be tried as an immunizing agent against *B. ovis*, it is necessary to give a brief account of the "*B. welchii* group."

The writer (loc. cit.) has discussed the antigenic relationships of the members of this group, viz., *B. welchii*, the lamb dysentery bacillus, *B. paludis*, and *B. ovis*. On account of the morphological and cultural resemblances of the last organism to *B. welchii*, we hesitated before giving it specific identity instead of describing it merely as a type of *B. welchii*. It was pointed out that the group required further investigation. Previous classifications of *B. welchii* have been based on purely biochemical grounds and antigen relationships have not been considered. Wilsdon (5), however, has recently published a more satisfactory classification based on toxin antitoxin relationships. The classical *B. welchii*, the lamb dysentery bacillus *B. paludis*, and another type of *B. welchii* of animal origin are classified as *B. welchii* types A, B, C, and D respectively. He suggests that the toxin of type A contains only one antigenic unit which is common to all four types, whereas type B, the lamb dysentery bacillus, contains three, one of which is common only to it and type C. Type D contains two, one common only to it and to type B, the second being the unit common to all the types.

Although there are slight cultural differences between the lamb dysentery bacillus and *B. paludis*, their toxins and antisera give complete cross immunization, and the organisms can only be satisfactorily differentiated by means of the relationship of their toxins and antisera to those of Wilsdon's *B. welchii* type D, or to *B. ovis*. The two latter organisms may prove to be identical, although the properties of the toxin of type D as described by Wilsdon differ in certain respects from those possessed by *B. ovis*. Dalling (2) apparently considers that *B. ovis* is identical with *B. paludis*.

This finding is difficult to understand in view of our results (Bennetts loc. cit.) which were checked by Dr. A. W. Turner, in Melbourne, and have since been confirmed by Gill (3) for both Western Australian and New Zealand strains of *B. ovtoricensis*.

In a personal communication early in 1932, Dr. L. B. Bull, Director of the Pathological and Bacteriological Laboratory, Adelaide Hospital, suggested an antigenic relationship of the members of the *B. welchii* group which was somewhat similar to that later reported by Wilsdon. From a consideration of our findings with regard to the toxin-antitoxin reactions in the group, he thought that the lamb dysentery bacillus toxin might contain the most evenly balanced mixture of antigenic components, and that consequently it might be advantageous to use this organism for prophylactic immunization against *B. ovtoricensis*. A further argument in favour is that this organism produces a much more potent toxin than does *B. ovtoricensis*.

An attempt was made to immunize guinea pigs against *B. ovtoricensis* toxin by means of lamb dysentery anaculture. Filtrates of the culture from which this was prepared had a mouse minimum lethal dose of 0.01 cc. Each of a series of guinea pigs was inoculated with an initial dose of 1 cc. of this vaccine, followed three weeks later by a second inoculation of 2 cc. A parallel series of guinea pigs were inoculated with the same amounts of *B. ovtoricensis* anaculture (mouse M.L.D. 0.1 cc.). The inoculations were subcutaneous. Three weeks after the second inoculation, the immunity was tested by intramuscular inoculation with solutions of standardized desiccated *B. ovtoricensis* toxin. The guinea pigs which had been inoculated with *B. ovtoricensis* anaculture survived the effect of 1 M.L.D. of toxin, but those receiving 5 M.L.D. died some hours later. On the other hand, lamb dysentery anaculture (made from a more toxic culture) gave no protection against even 1 M.L.D. of *B. ovtoricensis* toxin, animals receiving this dying as rapidly as the controls. Admitting that, as found by other observers, the immunity response is not good in guinea pigs, the result of this experiment was distinctly discouraging, and on account of the pressure of other work, the investigation was not carried any further.

If, as seems very likely, the arrangement of antigenic constituents in the toxin of *B. ovtoricensis* is similar to that of Wilsdon's *B. welchii* type D, the reason for the failure of lamb dysentery antigen to immunize against this toxin would be quite clear.

7. Further Field Work.

The prophylactic inoculation of sheep with *B. ovtoricensis* anaculture is being carried out under the supervision of the Western Australian Department of Agriculture. Already, applications have been received for the inoculations of some 25,000 sheep this season, and this work is proceeding.

An experiment is projected, the purpose of which is to determine experimentally the duration of immunity following on routine vaccination procedure.

8. References to Literature.

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- (4) Glenny, A. T., Buttle, G. A. H., Stevens, M. F.—*J. Path. & Bact.* 34 : 267–275, 1931.
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Some Preliminary Tests on the Control of *Thrips imaginis* Bagnall.

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Summary.

During the spring of 1932, preliminary tests were made with certain materials as repellents or deterrents for thrips. The work was considerably hampered by the cold weather during October, which necessitated a curtailment of the planned programme of experiments. The sprays tested were lime-water and lime-sulphur and resin; the dusts were nicotine, sulphur, and pyrethrum. Pyrethrum powder, even when mixed with sulphur in the proportions of 1 part of pyrethrum to 10 parts of sulphur, was shown to retain its strength as a repellent for two days. The other substances tested were of no value.

1. Introduction.

A series of tests with certain materials was carried out during the spring of 1932 for the purpose of determining the repellent value of the materials. In all, 100 separate experiments were made, from the end of August until the middle of November. The unfavorable weather conditions prevailing during October, when apple trees were blossoming, rendered it difficult to obtain any results during that month. However, such results as were obtained, combined with those from tests carried out in September and November, when the weather was more settled and the thrips more abundant, are sufficient to show the value of certain preparations, and the results that may be expected with others. The following materials were tested:—*Sprays*—lime-water, and lime-sulphur and resin. *Dusts*—sulphur and pyrethrum (separately and combined), a proprietary nicotine dust, and a proprietary nicotine-tar dust. These were chosen as having possible value either as repellents or deterrents, or as possessing killing properties in addition to repellent ones. No tests were made with insecticides as such, the work of Zeck and Noble† having demonstrated the value of kerosene emulsion, a cheap and easily prepared spray, in this connexion.

Although *Thrips imaginis* is the insect responsible for certain damage to deciduous fruit blossoms, three other species of thrips occurred in small numbers in nearly every sample of blossom taken during the spring. These were *Isoneurothrips australis* Bagnall, *Thrips tabaci* Lind., and *Haplothrips victoriensis* Bagnall. For record purposes, the insects taken in every count were separated into species, sexes, adults, and nymphs; but for the purpose of the tests, the total number of thrips in the blossom examined was used as an index to the efficiency of the treatment.

2. Treatment.

(i) *Lime-water*.—Experiments were made with lime-water as a spray, owing to its supposed efficacy as a thrips deterrent, reports having been received of the success attending its use during the 1931 thrips

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† Zeck, E. H., and Noble, N. S.: *Agric. Gaz. N.S.W.* 43: 231, 1932.

outbreak. It was made up in the proportions of $\frac{1}{2}$ lb. of fresh lime to 1 gallon of water. In four tests, the average number of thrips per blossom (plum and apple) 24 hours after treatment was 2.2, compared with an average number of 3.3 thrips in the untreated controls. The numbers of blossoms examined in these experiments were 190 treated, and 240 controls. In two instances the blossoms were scorched. This spray has no deterrent value.

(ii) *Lime-sulphur and Resin*.—This spray was tested in the proportions given in a previous publication (Coun. Sci. Ind. Res. (Aust.) Pamphlet 30, 1932), where it was stated that it had given promising results in laboratory and small field tests. It had been noted during the spring of 1931 that while lime-sulphur was of no value against thrips, owing to its poor wetting and sticking properties, when added to a solution of resin dissolved in methylated spirits and ammonia it became an efficient contact insecticide, and had some repellent value. The tests carried out in 1932 demonstrated that its repellent qualities are too short-lived to be of any real value.

(iii) *Nicotine Dusts*.—Two proprietary nicotine dusts were used in order to compare their efficiency with pyrethrum. It was found that they killed thrips quicker than pyrethrum, but that their effect was not lasting. A nicotine-tar dust gave promising results early in the season when the temperatures were low, but during hot weather this advantage over the ordinary nicotine dust was not apparent. Twenty-four hours after the application of nicotine dust to five roses, 218 thrips were found in them, while there were 422 thrips in the five roses examined for control purposes. A similar result was obtained with apple blossom, in which an average of six thrips a flower was found in dusted blossoms 48 hours after treatment, while an average of three thrips a flower was found in the control blossom. With nicotine-tar dust, 48 hours after its application to plum blossom, the average number of thrips in one blossom was 0.9, while the average number in the controls was 1.2; 240 treated flowers and 220 control flowers were examined in the experiment.

(iv) *Sulphur*.—Sulphur dust was tried out early in the season. It has little repellent value. With *Prunus pissardi* one hour after treatment, the average number of thrips per blossom was 1 (196 blossoms), controls 1 (142 blossoms). After 24 hours, the numbers were 1 (292 blossoms), controls 2 (157 blossoms).

(v) *Pyrethrum*.—Two brands of pyrethrum were tested, a proprietary preparation, and an ordinary commercial pyrethrum powder. The latter differed from the former in not having a carrier incorporated with it. This dust was tested on account of its known insecticidal value and reported repellent qualities. On account of its prohibitive cost, a series of tests were made with pyrethrum and sulphur mixed together in different proportions. Sulphur was chosen as a carrier as it is a heavy dust, and settles quickly; it is also inexpensive. Experimental applications of the dust were made with pyrethrum alone and with pyrethrum mixed with sulphur in the proportions of 1 part of pyrethrum to 4, 5, 8, and 10 parts of sulphur (by weight). It was found with all tests that, even when diluted in the proportions of 1 part of pyrethrum to 10 parts of sulphur, almost complete control of thrips was obtained over a period of 48 hours from the time of application. In five experiments with dust at the latter strength, a total

of 88 thrips was obtained from 670 blossoms of treated plum trees, 48 hours after application. From 378 undusted plum blossoms, 945 thrips were obtained.

During October, the weather was consistently cold, and no opportunity offered of determining the lasting qualities of pyrethrum on apple blossom during hot weather. In order to obtain some idea of this important point, during November, 40 Cecil Brunner roses growing on one hedge were dusted thoroughly with 1 part of pyrethrum mixed with 8 parts of sulphur. The roses were not fully open, and so the dust was unable to penetrate into the blossom. The numbers of insects in both treated and check flowers increased during the first three days as the developing roses became more attractive, and the temperature increased. The numbers dropped on the fourth day with the temperature, and as the roses had passed their prime. Ten dusted roses and ten untreated ones, at a corresponding stage of development from a neighbouring hedge were picked, and their thrips population recorded every day for four days. The maximum shade temperatures for the four days were 24.3° C., 28.3° C., 32.1° C., and 22.2° C. The numbers of thrips in the dusted flowers examined on the four days were, 50, 121, 332, and 601, and the numbers in the check flowers, 249, 440, 1,704, and 540 thrips respectively. This test demonstrated that pyrethrum retains its properties for three days at a high temperature, but not for four.

Included in the programme of tests planned for October were dusting experiments on blocks of apple trees in different stages of blossom development, from early pink-bud stage to full bloom. However, it was possible to undertake only a few of the intended series, and with only one series were any significant results obtained. The other series were either spoilt by wet weather or rendered valueless by the small numbers of thrips in the check blossom, often as low as an average of 1 thrips to 2 flowers.

Five Cleopatra apple trees in full bloom were dusted each with $\frac{1}{2}$ lb. of dust (1 part pyrethrum and 5 parts sulphur). After 24 hours, a total of 3 thrips were obtained from 204 blossoms picked at random. From 196 blossoms picked from check trees, 415 thrips were obtained.

3. Discussion and Conclusions.

Results of previously published experiments (Coun. Sci. Ind. Res. (Aust.) Pamphlet 30, 1932) demonstrated that sprays containing strong smelling essential oils, known to be repellent to thrips, are of no practical value in the field, their effect being too short-lived. Contact insecticides are of little value for the same reason. The substances dealt with in this paper have one feature in common—they leave a deposit on the leaves and petals to which they are applied. In the case of lime-water, the deposit is inert, but it was considered that a coating of lime might deter the thrips from feeding on sprayed blossom.

Dusts have frequently been advocated for use in the control of thrips, since, in a given time, it is possible to cover a larger acreage with a dust than with a liquid spray. A dust can be thrown over a tree as a cloud, whilst, to be of any value, spraying entails careful work, the nozzle being applied in turn to each cluster of blossoms.

However, if a dust is to serve the double purpose of acting as a contact insecticide and as a subsequent repellent, it is essential that a good cover be given. Consequently, unless the material used is cheap

and can be put on generously, it must be applied as in spraying, each of the individual clusters, as far as possible, receiving an application. The sepals, calyx cups, and flower stalks of apple blossom are hairy; this facilitates the retention of the dust, which is an important factor. In the experiments described in this paper, sulphur was used with pyrethrum on account of its cheapness and weight. Being a heavy dust, it settles quickly; a lighter material, unless applied in very still weather, is largely carried away by the wind, only a little settling on the tree. Sulphur has poor sticking qualities. During the course of some experiments carried out at the Gipsy Moth Laboratory, in America,* some promising adhesives were found; these, in the approximate order of importance, are, commercial ferric oxide, powdered casein glue, linseed oil or fish oil, and finely powdered milk. The best results were obtained when the powdered adhesive made up 20 per cent. of the weight of the dust mixture. Other recent work in America,† having as its purpose the development of dusts with better sticking qualities than those ordinarily used, has shown that increased adhesiveness can be obtained by adding small quantities of mineral oil to the dust.

In a previous publication on the control of thrips, to which reference has already been made in this paper, it was pointed out that, even during a season when thrips are present in "plague" numbers, it is only on days with very high temperatures that the insects are in sufficient numbers to constitute a danger to apple blossom. It was also shown that these periods are of short duration, seldom lasting even as long as four days. Pyrethrum, when mixed with sulphur in the proportion of 1 part of pyrethrum to 10 parts of sulphur, has been shown to give effective protection for two days when it is applied thoroughly to blossom, and not as a cloud. This is probably the longest period over which protection can be expected during such weather; buds that have been dusted on the outside will open and expose untreated petal surfaces, and it is doubtful whether pyrethrum is repellent except at very close quarters.

The wholesale price of imported pyrethrum in Australia is 2s. 6d. a lb., and the use of this dust, unless produced locally and the price very considerably lowered, will not be economically possible unless diluted with a carrier.

It must be stressed that the experiments carried out to date have been designed more for the purpose of determining the nature of materials suitable for thrips control, rather than a search for any specific substance. The results given in this paper are only a further step in the development of the investigation. Many substances and methods of application have yet to be tested.

Acknowledgments.

The work was carried out under the direction of Dr. J. Davidson, at the Waite Agricultural Research Institute, Adelaide.

I am indebted to Mr. N. Wicks, of Balhannah, for putting blocks of trees in his orchard at my disposal for field tests, and to Mr. G. Quinn, Chief Horticultural Instructor in South Australia, and Mr. R. Fowler, Manager of the Government Experimental Orchard, for the facilities made available at the Blackwood Orchard.

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The Hydrogenation of Coal and Oil.

By *L. J. Rogers, M.Sc., B.E.*

1. Introduction.

In 1930, Dr. A. C. D. Rivett, Chief Executive Officer of the Council for Scientific and Industrial Research, made some inquiries into the position of industries for producing oil from coal in England and Germany. His observations are embodied in a report* submitted to the Vice-President of the Executive Council. At that time little information had been published about the catalytic hydrogenation of coal and tar, which is probably the most promising process for converting coal into oil in Australia. A considerable amount of publicity has been given to this process lately in England, and to a lesser extent in Australia also. The following description of the process, its achievements, limitations, and present stage of development may therefore be of some interest.

If various solid and liquid fuels be compared on the basis of their ultimate analysis, it becomes evident that, with one or two unimportant exceptions, the order of increasing value is also the order of increasing hydrogen-carbon ratio. In the following table of representative analyses, the "disposable" hydrogen is the percentage present in excess of the quantity required to combine with the oxygen in the fuel.

ULTIMATE ANALYSES OF TYPICAL FUELS.

(On a dry and ash-free basis.)

—		Wood.	Peat.	Lignite.	Bituminous Coal.		Petroleum.	
					Non-coking	Coking.	Fuel Oil.	Petrol.
Carbon	%	50	57.5	70	81	86	86.1	85.3
Hydrogen	%	6	5.5	5	5.3	5.4	11.8	14.7
					Including an allowance for sulphur			
Oxygen	%	43	35.0	23	12	6.5	1	..
"Disposable" Hydrogen	%	0.6	1.1	2.1	3.8	4.6	11.7	14.7

The processes by which coal and petroleum have been formed in nature have involved the loss of water and gases rich in carbon. Hydrogen has, therefore, become more and more concentrated in the residue. Different grades of solid fuels represent the different stages at which the natural process of development has been arrested. The more mature coals are, therefore, richer in available hydrogen than the younger fuels. By inducing these fuels to combine with more hydrogen, it is possible to imitate the maturing process in the laboratory, and so obtain products of higher unit value. In this way a material resembling coal has been prepared from wood; non-coking coal has been transformed into coking coal; a liquid resembling crude petroleum has been produced from lignite and coal; and heavy oils and tars have been converted into petrol. This is the process which is now being developed under the name of hydrogenation.

* "Memorandum on the Present Position of Investigations on the Production of Oil from Coal," by A. C. D. Rivett, M.A., D.Sc., Parliamentary Paper No. 178. F.1064. Govt. Printer, Canberra (1931).

2. Historical.

Coal was first hydrogenated in 1868 by Berthelot, who obtained a mixture of organic liquids by heating coal under pressure with hydriodic acid. Bergius's first experiments were undertaken in an investigation into the origin of coal. By heating cellulose in an autoclave with water, he produced a material resembling coal, and concluded from his experiments that liquid hydrocarbons could be formed by carrying the process a stage further. Bergius's original patents were taken out in 1913 and 1914, but further progress was delayed by the war. By 1921, a semi-commercial plant had been put into operation at Rheinau, and in 1928 a plant with a capacity of 100 tons per day was constructed at Duisberg. The process soon proved to be uneconomic, however, and the plant was closed down.

The original Bergius process converted coal into a mixture of motor spirit, a phenolic middle oil, and pitch, roughly in equal proportions. In the last ten years, investigations with which Bergius has had no connexion have proved the possibility of preparing petrol as the only liquid product. These developments have been effected by the German chemical combine (the *Interessen Gemeinschaft*) and by Imperial Chemical Industries. Credit for the original idea must be given to the German company, which has confined its attention largely to the treatment of brown coal tar. In England, Imperial Chemical Industries has attacked the more difficult problem of hydrogenating solid coal, with very satisfying results from a technical, if not from an economic, point of view.

The results achieved in Germany were so encouraging that, in 1928, the Standard Oil Company purchased a half interest in the I.G. process. In the last two or three years, a combine of world-wide interests has been formed for the pooling of patent rights, and the control of the hydrogenation process. The partners in this combine are the *Interessen Gemeinschaft*, Imperial Chemical Industries, the Royal Dutch-Shell group, the Standard Oil Company, and, through the latter, most of the oil companies of America.

The present position of the industry is roughly as follows :—In Germany there are three plants in operation, a large one at Leuna, near Leipzig, and two smaller ones at Merseburg and Oppau. About 400 tons of petrol are produced per day from brown coal tar and heavy petroleum residues. The Company claims to have hydrogenated brown and black coal successfully, but the prices of raw materials at present are such that the treatment of brown coal tar is a more economic proposition.

At Billingham-on-Tees, in England, there is a 15-ton per day pilot plant, upon which sufficient work has been done to enable a full-scale commercial plant to be designed. The operation of the 15-ton unit itself is not economic, so it has been closed down for the last year.

In the United States of America, two oil hydrogenation plants have been constructed with a capacity of 5,000 barrels (700 tons) per day each. The price of petrol in America is such that the hydrogenation of heavy oil to motor spirit is hardly possible commercially. Having satisfied itself, therefore, that petrol production presents no unsolved technical difficulties, the Standard Oil Company has set itself the task of investigating various special developments of the process. Asphaltic residues, which cannot be cracked in a plant of the orthodox type, have been found amenable to treatment with hydrogen. A motor spirit has been produced with a high flash point, and this product is being recommended for use in air craft, to reduce the fire risk. High-grade lubricants have been prepared from inferior stock. Hydrogenated lubricating oils indeed are much superior to the products prepared by

distillation alone, having a low setting point and a comparatively high viscosity at elevated temperatures. The Standard Oil Company is marketing an hydrogenated product under the name of "Essolube" for blending with ordinary lubricating oils. Such developments represent the most likely immediate field of application in the petroleum industry.

3. The Hydrogenation Process.

The original Bergius process seems so unlikely at present to make any commercial progress that no useful purpose would be served by describing its operation. The main difference between it and the modified processes employed by the Standard—I.G. Company consists in the use of catalysts, which, by speeding up the reaction, make possible a reasonable throughput for a plant of economic size. Effective hydrogenating catalysts, such as nickel, have been known for many years and have been widely employed in associated processes, such as the saturation of fish oils. But the catalysts used until ten years ago were susceptible to poisoning by sulphur, and, therefore, could not be applied to the hydrogenation of coal, tar, and crude oil. An intensive search in the last ten years has resulted in the discovery of many other catalysts, such as molybdenum oxide, molybdenum sulphide, tungsten oxide, tungsten sulphide, and cobalt sulphide. These are just as effective as nickel, but they are immune to sulphur poisoning. It is this achievement, alone, which has enabled hydrogenation to reach its present stage of development, and which may in the future make commercial application possible.

The catalytic process for hydrogenating coal may be carried out in two or three stages. Two are used in England and three in Germany. In the first, pulverized coal is mixed with sufficient heavy oil to make a paste which may be pumped. After being heated to a temperature of about 450° C., it is forced into a vertical reaction vessel, constructed of a special alloy steel, and in which a pressure of 250 atmospheres is maintained. Hydrogen also is heated and pumped into the chamber with the coal paste. The operation is continuous, and the product from this stage consists of a mixture of light, medium, and heavy oils, and a small amount of solid matter. The crude product is fractionated at temperatures of 170° C. and 300° C. approximately. The spirit is sent to the refinery, the middle oil passes to the final stage of the process, and the heavy oil is centrifuged or distilled, to separate the original ash of the coal and what little unconverted material is present. In the two-stage process, the throughput of the first unit is adjusted to provide just sufficient heavy oil for pasting the raw coal. In the three-stage process, the throughput is increased, and the reaction is arrested at a stage where the product is mainly a heavy oil. After removal of solid matter from this oil, it is given a second treatment before proceeding, as a middle oil, to the final stage of conversion.

The middle oil is hydrogenated in the vapour phase at a temperature of about 500° C., but in the presence of hydrogen at the same pressure as before. After passing through the converter, the vapours are condensed and fractionated. The oils boiling outside the petrol range are returned to the plant, and re-cycled until conversion is complete. In this way, the original coal is ultimately transformed mainly into motor spirit, the yield being between 60 per cent. and 65 per cent. by weight of the dry ash-free coal, or approximately 190 gallons per ton. The other products are water, ammonia, gas, and a small quantity of incompletely hydrogenated material.

The temperature in each stage, and the catalyst employed, are chosen so as to give the best conversion in that stage to the desired products. In the liquid phase stages—the first of the English process, and the second as well in the German system—the catalyst is mixed with the charge. For the vapour-phase reaction, the catalyst is suspended inside the converter. Tar or heavy oil is hydrogenated in two stages, corresponding to the second and third (the “sumpf” and the “gas”) stages of the German process.

The motor spirit produced requires practically no refining, and is an excellent anti-knock fuel. The middle oils formed in the incomplete hydrogenation of coal are highly aromatic and phenolic, and therefore of doubtful value as a fuel for Diesel engines. The heavy oils from coal appear to have no constituents with lubricating properties of any value. The process is, therefore, essentially one for producing petrol.

In the conversion of bituminous coal into petrol, the consumption of hydrogen is 9 or 10 per cent. by weight, or roughly 35,000 to 40,000 cubic feet per ton. For treating tar, only half this quantity is required, and for petroleum residues still less. In addition to the hydrogen actually absorbed, a considerable excess must be passed through the plant to prevent coking. In the vapour phase stage, the hydrocarbon gases generated in the process must not be allowed to dilute the hydrogen to a concentration less than about 85 per cent. In the liquid-phase stage, a minimum concentration of 70 per cent. is satisfactory. Enormous volumes of hydrogen must therefore be manufactured for the process and compressed to a fairly high working pressure.

Hydrogen is manufactured on a very large scale in the synthetic ammonia industry. The favourite method of production is the catalysed reaction between steam and water gas at about 500° C. The carbon dioxide formed in the process and the residual carbon monoxide are subsequently removed by solution under pressure. Coke oven gas is also extensively employed for producing hydrogen by the Linde process, in which the other constituents are separated by liquefaction at low temperatures. In a few instances cheap electric power is used for generating hydrogen by electrolysis.

The excess hydrogen required for the coal treatment process may be recovered from the residual gases. The hydrocarbon gases formed may also be used as a source of part or all of the fresh hydrogen required. Steam is mixed with the gas and heated at a low pressure to a temperature of about 1000° C. The resulting mixture of gases is then converted into hydrogen by the processes applied to water gas or coke oven gas. Other gases may be substituted for process gas, water gas, or coke oven gas, if available cheaply. In one of the American plants, for instance, natural gas is used. Whatever may be the source of hydrogen, however, the cost of manufacture and compression is bound to be high. The lowest cost of hydrogen on a large scale and under European conditions is likely to be about 5d. per 1,000 cubic feet. The cost of manufacturing hydrogen, therefore, is roughly equivalent to 2d. per gallon of petrol produced.

High as this charge may appear, even this figure can be realized only by operating on a very large scale. The amount of power required for compressing and circulating hydrogen, and for other purposes, also indicates that a big production is essential for economy. In England, it is considered that the economic unit should have a treatment capacity of at least 500 tons, and preferably 1,000 tons of coal per day. In Germany, the development of the hydrogenation process is held to be linked with the ammonia industry so that each may benefit by the reduced price of hydrogen.

4. Economics.

It has been estimated by Imperial Chemical Industries that a plant for hydrogenating 1,000 tons of bituminous coal per day would cost about £8,000,000 sterling. The cost of operating the plant, when paying 12s. 6d. per ton for best small coal, would amount to 7d. per gallon. In order to attract investment in an enterprise of so speculative a nature, it would probably be wise to provide for liberal dividends, raising the total cost of production to 10d. Imported spirit is being landed in England for 1s. per gallon approximately, including 8d. duty. It would appear, therefore, that the commercial application of the hydrogenation process is dependent upon the continued imposition of this duty and exemption from any excise charges.

The Government has been urged at times to interest itself in the establishment of the industry as a means of relieving unemployment. The production of a 1,000-ton per day plant, however, would involve the Exchequer in a loss of £2,000,000 revenue per annum. The employment created directly or indirectly would only absorb 5,000 men approximately, so that the Government would be required to subsidize the industry to the extent of some £400 per annum for every man employed. When it is considered, furthermore, that the British Government and the investing public have large interests in oil companies, it is not difficult to understand some reluctance to invest money in hydrogenation.

It has been stated in England that motor spirit can be produced from tar costing 25s. per ton at the same price as from coal at 12s. 6d. per ton. Opinion appears to be growing that the hydrogenation of tar is a more attractive proposition than the treatment of coal. The total amount of tar produced in England, however, is only about 40,000,000 gallons per annum. Much of this would be unsuitable for the process, and the surplus available at 25s. per ton would not be sufficient for the operation of an economic unit.

Hydrogenated spirit has been sold on a large scale in Germany (400 tons per day) at 1s. 8d. per gallon retail price. Although the scale of operation may not be large enough for economic working as an independent industry, the works at Leuna and elsewhere enjoy the advantages of cheap hydrogen, tar, and power, owing to the fact that they are attached to synthetic ammonia plants. These are the conditions stated in Germany to be most favorable for hydrogenation. The Government has given concessions in railway freight to the domestic product, and a further advantage arises in the location of the plant remote from ports where foreign petrol is landed, but close to large markets and cheap supplies. Nevertheless, there is no record of the distributing company having made a profit, and it is reported that the Leuna factory was closed down for part of last year. At Oppau and Merseburg, a short week was introduced in order to reduce costs. Apparently, commercial operation is still uncertain even under German conditions.

No information has been published regarding operating expenses in the American plants. It has been stated, however, that the first works cost \$8,000,000 to erect, that the second cost \$5,000,000, and that subsequent plants of this size (700 tons per day) could be constructed for \$2,000,000. The lowness of these figures compared with the English estimate is rather surprising, even when due allowance is made for the extra plant required to treat coal.

5. The Prospects of Hydrogenation in Australia.

In spite of the low cost of brown coal in Victoria, it is probable that hydrogenated petrol would be more cheaply produced from New South Wales bituminous coal. There is no synthetic ammonia industry in Australia, which might enable hydrogenation to be practised on a comparatively small scale. Nor is there any appreciable quantity of tar available for conversion into motor spirit. The industry, therefore, will probably need to be established, if at all, with black coal as the raw material, and on a fairly large scale.

A plant with a capacity of 1,000 tons of coal per day would probably cost about £12,000,000 in Australia. Based upon comparative English estimates, the production costs, including interest charges, would probably amount to 1s. 3d. per gallon of petrol. Imported spirit can be landed at Australian ports, with duty and other charges paid, at the same price or even a little lower. The industry would enjoy no advantage in distribution expenses, for most of the product would need to be transported by sea to the main markets. In Australia, as in England, therefore, the successful application of the process, in the state to which it has been developed to-day, would seem to depend upon some form of Government subsidy.

Admittedly, many arguments may be advanced for the establishment of the industry even in the face of a certain loss. As a measure for relieving unemployment, however, it does not appear very attractive. It is to be hoped, however, that by accumulated experience and research in the operation of high pressure processes, such economies will be made that commercial application will become possible in Australia.

Ragwort Poisoning in Cattle in Victoria.

*By D. Murnane, B.V.Sc.**

1. Introduction.

Earlier experiments by Gilruth (Report of Division of Veterinary Science, N.Z. Dept. of Agric., 1901-2 and 1902-3), demonstrated the fact that ragwort (*Senecio jacobaea*) is toxic to horses, cattle, and sheep in New Zealand, and later (N.Z. Dept. of Agric. Report 1904) that sheep if fed on pasture lands almost exclusively occupied by ragwort would also become subject to similar pathological changes in the liver. Further, the Pictou cattle disease of Nova Scotia has been demonstrated by Adams and others to be due to ingestion of ragwort producing chronic liver changes. Although this plant is plentiful in certain parts of Victoria, we have not seen any authentic reports which conclusively establish the fact that the plant is toxic in this State.

The purpose of this note is to record findings which incriminate ragwort in the South Gippsland district.

* An officer of the Council's Division of Animal Health, located at the Veterinary Research Institute, Parkville.

In association with the Veterinary Branch of the Department of Agriculture of Victoria, a visit was made to a dairy farm at Toora where losses had occurred. It was ascertained from the owner that cows usually remained in good condition for about twelve months after arrival on the property, after which time, sooner or later they developed characteristic symptoms and died within three to twelve weeks. Most of the losses occurred during the spring months, but some deaths took place during the autumn.

Cattle were frequently seen eating ragwort, which is very plentiful in the locality, and which seems more palatable when dry after having been cut. Certain animals acquired a particular liking for the plant. Young cattle appear to become affected more quickly than do older animals. The owner has had no losses in animals other than cattle.

(i) *Symptoms*.—After grazing for twelve months or more on the property, cattle develop typical symptoms, exhibiting dullness, loss of appetite, a jaundiced condition of the eyes, together with a peculiar staring appearance. There is loss of weight, and, in the case of lactating animals, a very marked diminution in the milk supply. The milk itself has a peculiar odour and a pronounced acrid flavour, rendering it quite unfit for use. The affected animal frequently develops a scabby condition of the skin, particularly that of the udder and teats. In the later stages, there is impaired vision, staggering gait, persistent diarrhoea, a marked thirst, and progressive loss of condition. The milk supply ceases, food is not taken, the animal becomes weaker, goes down, and eventually dies—frequently in a swamp or waterhole into which it has wandered to quench its insatiable thirst.

(ii) *Post-Mortem Examination*.—An affected animal showing typical symptoms was killed and examined immediately.

The subcutaneous tissue and fat were very yellow. There was a considerable excess of straw-coloured peritoneal and pleural fluid. The rumen and omasum were partly filled with ingesta; the reticulum and abomasum were empty. The large and small intestines contained a small quantity of fluid ingesta. The submucosa of the abomasum was extensively infiltrated with clear semi-gelatinous fluid—to such an extent that the mucous membrane was thrown into folds, and the wall of the organ was increased in thickness to two inches. A similar condition existed throughout the whole length of the small intestine. In addition, the omentum and mesentery were highly charged with this clear, semi-gelatinous fluid, as were the whole of the mesenteric lymph glands, which were also rather haemorrhagic on incision. Much free fluid could be expressed from the incised glands. The bladder was empty, and the kidneys showed no abnormality. The liver was slightly blue in colour, firm, and rather elastic to the touch. The capsule was somewhat adherent, and did not strip as readily as normally. The gall bladder was distended. The lungs were normal; the heart showed sub-endocardial haemorrhages in the left ventricle.

Specimens were preserved and taken back to the laboratory for microscopical examination.

(iii) *Differential Diagnosis*.—As some of the symptoms—namely emaciation, persistent diarrhoea, decreased milk yield, normal temperature, impaired appetite, abnormal thirst, and exhaustion—are all

common also to subjects with Johne's disease, scrapings of the mucous membrane of the intestine were taken. Subsequent microscopical examinations, however, failed to reveal the presence of any acid fast organisms indicative of Johne's disease.

(iv) *Microscopical*.—In the liver there was congestion beneath the capsule, which was definitely thickened, with fibrous processes invading liver tissue, both inter- and intra-lobular, and in the region of the portal canals. Other organs were normal

(v) *Diagnosis*.—From the history, symptoms, post-mortem, and microscopical findings, it was concluded that the condition was that of chronic ragwort poisoning.

2. Feeding Experiment.

In order to confirm this finding, it was decided to obtain supplies of ragwort from this Gippsland property, and to feed it to a bovine at the Veterinary Research Institute.

A young bull received 336 lb. of the semi-dried flowering plant in daily doses extending over a period of six weeks. During the fourth week, the animal became visibly affected, and developed a marked thirst and persistent diarrhoea. By the fifth week, he was showing loss of condition, loss of appetite, profuse diarrhoea, and increasing thirst.

At the sixth week, the animal became prostrate and unable to rise, was dull, very much "tucked up," and refused all food. At the end of the sixth week, death took place.

(i) *Post-Mortem Examination*.—Such an examination was made immediately.

The only abnormalities were highly congested mucous membranes of abomasum, large and small intestines, with considerable gelatinous infiltration of the submucosa of abomasum and intestines. The liver was mottled and slightly tough to the touch.

(ii) *Microscopical Appearance of Liver*.—Although there appeared to be some increase in the amount of fibrous tissue present, there were no gross changes in the organ.

3. Conclusions.

Ragwort in the Gippsland district of Victoria is toxic to cattle, and apparently is responsible for losses in dairy herds in that locality.

The post-mortem findings very closely resemble those of ragwort poisoning described by Gilruth in New Zealand.

Eradication of the plant is recommended. Where this is not possible, the infested areas may be stocked with sheep, which, according to Gilruth's experience in New Zealand, can be utilized to eradicate the weed. Sheep suffer little effect from the toxic principle of ragwort save in cases where the pasture is almost entirely supplanted by the weed, and when the animals are so fed for prolonged periods. In any case, sheep can be sold and replaced each year, which would not be practicable with dairy cows.

Caseous Lymphadenitis Investigations.

1. Infection Experiments.

*By D. Murnane, B.V.Sc.**

Extensive observations, involving the manual examination of many thousands of sheep in different parts of Victoria during the past few years, have indicated that the percentage of infection is very much higher in machine-shorn than in blade-shorn sheep.

The suggestion has been put forward by various workers that in the case of machine-shorn sheep the greater degree of wounding—presumably with contaminated combs and cutters—has been responsible for the higher rate of infection. Others have expressed the opinion that, although the machine-shorn (and hence more severely wounded) sheep seem to contract infection more readily than blade-shorn animals, the actual inoculation of the wounds may not be commonly by means of contaminated shearing hand-pieces. Earlier experiments conducted by us on an infected property in Victoria (see this *Journal*, 4: 135, 1931) lend some support to this latter view.

Subsequently, Seddon and Belschner (*Agric. Gaz. of N.S.W.*, 43: 525, 1932) recorded details of an experiment which, they consider, gives every indication that the infection takes place in the counting-out pens and yards after shearing.

With the idea of investigating this point further, it was decided, at the suggestion of Dr. Gilruth, to carry out a further experiment at the above-mentioned infected Victorian property. Guinea pigs were used in the tests, as these animals are undoubtedly much more susceptible to caseous lymphadenitis infection than are sheep.

(i) *Experiments in Counting-out Pens and Yards.*

Group 1: 52 guinea pigs were transported to the property on the 20th October, 1932, immediately shearing operations had ceased. Each animal was closely clipped over the "withers," and two triangular flat-type wounds, with sides about $\frac{1}{2}$ inch in length, were made with sharp scissors in the clipped area. After bleeding had ceased, the animals were placed in a recently used small "counting-out" pen, beneath a large 6 feet x 4 feet fly-proof cover, and were allowed to run about. They remained in the pen for eight hours, during which time the dust was kept stirred up by "flopping" the surface of the pen with a sack.

The animals were then removed, replaced in separate tins with fly-proof covers, and brought back to the laboratory. The surface dust from the adjoining counting-out pen was swept up and also brought back to the laboratory. This material was used for treating further groups of animals.

Group 2: 25 guinea pigs were similarly clipped and wounded, and rather freely dusted with the counting-out pen sweepings. Each animal was then placed in a separate tin with fly-proof lid.

* An officer of the Division of Animal Health, and located at the Veterinary Research Institute, Parkville.

Group 3: 25 guinea pigs received similar treatment to those in Group 2.

Group 4: 25 guinea pigs received treatment similar to those in Group 2, except that the dusting was very light.

Nine days after exposure to infection, 2 animals of Group 1 died; within seven days of exposure to infection, 13 animals of Group 2 died; within six days of exposure to infection, 8 animals of Group 3 died; and within six days of exposure to infection, 11 animals of Group 4 died.

Post-mortem examinations were made. No internal lesions were found. Deaths were apparently due to septicaemic conditions. From the heart blood of some of the dead animals, growths of gram-positive cocci and gram-negative bacilli were obtained.

Six weeks after exposure to infection, the remaining animals in each group were killed and subjected to careful post-mortem examinations.

Results.—The results were as follow:—

Group 1: 50 animals remained—no lesions.

Group 2: 12 animals remained—no lesions.

Group 3: 17 animals remained—no lesions.

Group 4: 14 animals remained—no lesions.

Comment.—While it would be necessary to confirm the above findings by further tests before arriving at any definite conclusion, it would appear that the dust in the counting-out pens is not a serious source of infection, at least for the guinea pig, although this animal is much more liable to contract caseous lymphadenitis than is the sheep.

(ii) *Experiments with Surface Soil from Sheep Camps on Affected Properties.*

Surface soil from sheep camps on each of three affected properties was obtained. In each case, the soil sample consisted of surface dust taken from several camps on different parts of the property.

Group 1: 8 guinea pigs, each of which had previously received a dose of 100 units of veterinary tetanus antitoxin, were closely shorn over the withers. Each received two triangular flap-type wounds, about $\frac{1}{2}$ inch long, extending through the skin and into the subcutaneous tissue. The powdered surface soil from C.'s property was dusted over the wounds; the animals were then placed in separate fly-proof containers.

Group 2: 8 guinea pigs received similar preliminary treatment, and were dusted with soil sample from E.'s property, and were placed in separate fly-proof containers.

Group 3: 8 guinea pigs received similar preliminary treatment, and were dusted with soil from J.'s property, and were placed in similar containers.

Within a few days of treatment, two animals of Group 1, one of Group 2, and one of Group 3, died. (Owing to the absence of the writer, no post-mortem examinations were made.)

Seven weeks after treatment, all animals were killed, and careful post-mortem examinations were made.

Results.—The results were as follow:—

Group 1: 6 animals—no lesions.

Group 2: 7 animals—one showed a large abscess in the spleen, from which a pure culture of a gram-positive coccus was obtained. One showed several small nodules in the spleen, from which pure cultures of (a) a gram-positive coccus, and (b) a gram-negative bacillus were obtained.

Group 3: 7 animals—no lesions.

2. Infection Tests with Accumulated Faeces from Shearing Sheds where Caseous Lymphadenitis is frequent.

By H. R. Carne, B.V.Sc.

(From the Pathology Department, F. D. McMaster Animal Health Laboratory.)

Supplies of faeces were obtained from the counting-out pens of the shearing sheds on three properties, on which a considerable incidence of caseous lymphadenitis was known to occur in adult sheep which had been on these properties since birth. Care was taken to collect faeces from pens in which they were sheltered from direct sunlight, as it is known that the latter destroys *Corynebacterium preisz-nocard*† in a few hours.

Sample A was tested on 20 guinea pigs.

Sample B was tested on 20 guinea pigs.

Sample C was tested on 30 guinea pigs.

Ten guinea pigs were used as controls.

The experiment was carried out in the following manner:—

Guinea pigs were run separately in cages made from new kerosene tins. These cages, in addition to having wire-netting tops, were covered by a fine mesh cheesc-cloth, and thus rendered fly-proof. In order to protect the guinea pigs from infections by pathogenic anaerobes, which commonly occur in faeces, each animal, except the controls, received 1.0 cc. of a mixture of antisera prepared against *B. welchii*, *Vibrio septique*, *B. oedematiens*, and *B. tetani*. The following day, each guinea pig was clipped over the withers, and two V-shaped wounds about 1 to 1.5 cm. long were made in the skin over the withers. Several hours later, when bleeding and exudation from these wounds had ceased, the sample of faeces to be tested, after having been reduced to a coarse powder by passing through a fine mincing machine, was dusted freely on to the surfaces of the wounds and gently rubbed well under the flaps of skin. The floor of the cage in each case was covered with a layer of the same ground-up faeces to a depth of about $\frac{1}{2}$ inch, and this layer was renewed twice weekly when the cages were cleaned. The mash and green feed on which these animals were fed were dropped on to the floor of the cage, there being no containers to prevent the food becoming

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† Also referred to as the "bacillus of Preisz-Nocard," or the "Preis-Nocard bacillus."

contaminated with the powdered faeces. It was thought that, by doing this, opportunities of infection by ingestion would be added to infection through the wounds.

The process of wounding and contaminating wounds with faeces was repeated on each guinea pig fourteen days after the first wounding. Animals were then kept for one month, when all were killed and submitted to a detailed post-mortem examination.

The ten control animals received no antisera, nor were their wounds dusted with faeces. The floors of their cages were covered with sawdust. Otherwise, they were kept under the same conditions as the test guinea pigs, and were wounded twice at the same time as these.

Particular care was taken to keep the animals fly-free, and when the cages were being cleaned twice weekly, the attendant, after disinfecting his hands, placed the guinea pig whose cage was to be cleaned into a clean cage with a layer of sawdust on the floor moistened with disinfectant. No disinfectant was used in the experimental cages, which were merely scraped out and a fresh supply of ground-up faeces sprinkled on the floor.

Ten guinea pigs died during the course of the experiment, eight amongst the experimental lots, and two controls. In only one of these were any lesions found which bore any resemblance to those produced by *C. preisz-nocard*. This was a guinea pig in one of the experimental lots which accidentally strangled itself on the seventh day after the second dusting by becoming entangled in several loose strands from the cheese-cloth cage covering. On post-mortem examination, the wounds were found to be almost completely healed, and showed no evidence of any undue inflammation. The tissue beneath the wounds appeared quite normal, but the right axillary lymphatic gland was enlarged to about twice its normal size, and was firm and juicy. No abscesses could be detected in its substance, but on culturing pipettes of material taken from the pulp, a mixed culture of diphtheroid bacilli was obtained. One of these organisms was morphologically identical with *C. preisz-nocard*, but on cultural examination it proved to be different. This animal was quite lively and strong before it was killed.

The other 60 guinea pigs remained in vigorous health throughout, and on post-mortem examination a detailed examination of all the lymphatic glands and organs failed to reveal any sign of abnormality in any case, apart from one or two parasitic lesions in the liver. The wounds, in spite of gross contamination with faeces, appeared to heal rapidly in all cases, and a careful examination of the subcutis beneath the wounds failed to show any pathological changes, nor while the animal was alive was definite suppuration detected in any wound during the process of healing.

This experiment thus failed to detect the presence of *C. preisz-nocard* in the three samples of faeces tested.

NOTE.—The faeces used in these experiments were collected from pens underneath the shearing shed which were protected from direct sunlight. One lot was rather dried up; the others still contained some moisture. The exact date of collection after shearing is not known, but it must have been a matter of a couple of months.

3. Percutaneous Infection of Guinea Pigs and Sheep with Caseous Material from Natural Lesions of Caseous Lymphadenitis.

By H. R. Carne, B.V.Sc.*

(From the Pathology Department, F. D. McMaster Animal Health Laboratory.)

Four guinea pigs were clipped over the withers with scissors, great care being taken not to injure the skin in any way. The clipped area was then gently inoculated with fresh caseous material from a natural lesion on a sheep. By cultural examination, this lesion was found to contain numerous *Corynebacterium preisz-nocard* in purity. The material was gently rubbed in with the smooth rounded end of a small glass pestle.

Five days later, three of the guinea pigs showed some dried serous exudate on the surface of the skin over the inoculated area. The pre-scapular and axillary lymph glands draining the treated area appeared normal on palpation. These changes in the skin disappeared in the course of a few days in two of the pigs, but in the third, loss of hair over the affected areas, followed by the formation of small discrete abscesses in the skin and subcutis occurred. One of these abscesses ruptured on the 11th day, and another on the 27th, but several others persisted up to the 46th day, when this animal was killed.

Enlargement of the axillary and/or pre-scapular lymph glands was observed in three animals. The earliest glandular involvement was observed on the eleventh day, but all three animals showed abscesses in pre-scapular or axillary lymph glands on one or both sides by the third week.

One guinea pig died on the 33rd day, and the remainder were killed on the 46th day. In all but one animal, which appeared quite healthy, well developed abscesses containing numerous *C. preisz-nocard* in a state of purity were present.

Percutaneous Infection.—The following results were obtained, the experimental sheep being treated similarly to the guinea-pigs:—

(a) *With Corynebacterium preisz-nocard.*

- | | |
|--|---|
| Culture alone .. | <i>Sheep.</i> —One lamb did not become infected.
<i>Guinea Pigs.</i> — |
| Culture in lanoline .. | <i>Sheep.</i> —One lamb developed two small nodules in the skin. No glandular lesions.
<i>Guinea Pigs.</i> — |
| Caseous material from natural lesions .. | <i>Sheep.</i> —One lamb did not become infected.
<i>Guinea Pigs.</i> —Three out of four became infected. |

(b) *With Corynebacterium pyogenes.*

- | | |
|------------------------|---|
| Culture alone .. | <i>Sheep.</i> —One lamb did not become infected.
<i>Guinea Pigs.</i> —Two guinea pigs did not become infected. |
| Culture in lanoline .. | <i>Sheep.</i> —One lamb did not become infected.
<i>Guinea Pigs.</i> —Two guinea pigs did not become infected. |

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The Manganese Content of some Australian Timbers.

By W. E. Cohen, B.Sc.,* and A. B. Jamieson, M.Sc.*

1. Introduction.

The element, manganese, is known to be distributed universally throughout the plant kingdom and to fluctuate more in amount than do most of the other elements that may be found in plants(1). It generally reaches its highest concentration in the leaves and seeds. Many theories have been advanced with respect to its function, but it is not intended to discuss them in this paper†.

Gössl(2) found that swamp plants and water plants, in general, contain more manganese than do dry land plants, and that the evergreens have a greater quantity than the deciduous trees. It has been stated that the total amount of this element in the plant will vary with the nature of the soil, although Kleinstuck(3), who examined the leaves, bark, and wood of the more important European trees, found its occurrence to be quite arbitrary, i.e., without any relation to the locality, the soil, or the age of the tree.

The manganese contents of the ashes of various timbers have been recorded from time to time. Amounts up to as much as 3 per cent., estimated as Mn_3O_4 , have been found in the ash of oak, 4.85 to 7.74 per cent. in that of beechwood, and 10 to 18 per cent. in that of birch. However, in some cases, much lower values are found in these woods. Dittman(4) found that the stemwood of beech was much richer in manganese than the branchwood. The highest recorded value for manganese (Mn_3O_4)—in the ash of *Abies pectinata*—was 40 per cent. Kleinstuck(3) has recorded the manganese content as mgms. of manganese per 100 grams of completely dried material as follows (see Table 1):—

TABLE I.—SHOWING THE MANGANESE CONTENT OF THE LEAVES, BARK, AND WOOD OF THE MORE IMPORTANT EUROPEAN TREES. (MGMS. OF MN. PER 100 GMS. OF COMPLETELY DRIED MATERIAL.)

Tree.	Stem Wood.	Bark.	Leaves or Needles.
Pine	9.2	53.1	16.1
Fir	1.1	11.1	27.5
<i>P. sylvestris</i>	11.9 (pith)	17.2	35.0
Larch	18.9 (pith)	4.4	74.8
Oak	0.03 (pith)	28.0	41.6
"	4.4 (sap)	..	..
Red beech	16.4	112.0	94.5
Hornbeam	8.0	345.2	158.2
Birch	0.7	6.5	67.0
Maple	1.3	12.6	90.3
Linden	1.7	11.0	10.3
Ash	0.8	3.1	1.8
Alder	1.2	7.7	3.7
Poplar	2.1	12.5	5.4

* Officers of the Division of Forest Products.

† It might be mentioned, however, that an interesting instance of the effect of a lack of manganese occurs in South Australia, where in certain parts barley cannot be successfully grown until the soil has been given a small application of manganese sulphate.

With reference to Australian timbers, Baker and Smith(5) recorded the manganese content of the ashes of a number of Australian pines, and discussed the association of this element with the exudations from these trees. They stated that for all the conifers of Australia that they had tested, the element proved to be a necessary constituent for the best growth of the trees. Simpson(6) observed that the ash of salmon gum (*Euc. salmonophloia*) is unusually rich in manganese, the ash of the branches containing over 3 per cent. Mn_2O_4 , while that of the main trunk contains 2.5 per cent. Tuart (*E. gomphocephala*) contains about 1.5 per cent., while karri (*E. diversicolor*) and jarrah (*E. marginata*) contain less than 1 per cent. expressed as a percentage of the ash.

2. Recent Observations of the Occurrence of Manganese in Australian Timbers.

(i) *Tasmanian Myrtle* (*Nothofagus cunninghamii*).—During the determination of the alkalinity of the ash (7, 8) involved in a study of chemical differences between the sapwood, intermediate wood, and truewood of Tasmanian myrtle (*Nothofagus cunninghamii*), a high percentage of manganese was suspected, for on the dissolution of the ash in dilute acid there developed a pink colour which interfered with the back titration of the excess acid using phenolphthalein indicator.

A procedure, briefly described below, was employed in order to determine the manganese content of samples of sapwood, intermediate wood and truewood taken from three cross sections of the bole of a tree, viz., butt, mid-log, and top. The results were expressed in terms of milligrams of Mn_2O_4 per 100 grams of oven-dried (105° C.) wood. This method of expression has been adopted because experience has shown that results expressed as a percentage of the ash are inconsistent, and cannot be duplicated with any great measure of accuracy. The manganese contents of the sapwood and intermediate woods were found to be much the same, varying from 10.7 mgms. to 14.9 mgms., these extremes both occurring in the intermediate wood. In the same tree, the truewood contained from 6.4 to 9.4 mgms. On the examination of two further cross sections taken from another and larger tree, the manganese content of the sapwood and intermediate wood ranged from 4.53 to 6.23 mgms., while that of the truewood varied from 1.88 to 4.45 mgms. Although little value can be placed on results expressed as a percentage of the ash, the following figures are quoted in order to afford a comparison with figures for other woods already expressed in this manner. In the first tree, the manganese content of the ash of the sapwood and intermediate wood varied from 2.4 to 4.7 per cent., while that of the truewood ash ranged from 2.7 to 4.5 per cent. In the second tree the ranges were from 0.8 to 1.1 per cent. in the ash of the sap and intermediate woods, and from 1.1 to 1.9 in the truewood ash.

With reference to the supposed relation of manganese to the extraneous materials contained in some woods, the following results are of interest. The wood of Tasmanian myrtle is found in two types, the white and the red. The trees producing these two different types of wood may grow alongside one another. Samples of the white type were found to contain from 7.55 to 8.50 mgms. of manganese per 100 grams of oven-dried wood, while those of the red type were found to

vary from 5.53 to 11.45 mgms. From this, it would appear that the manganese is not directly associated with the colouring substance in the red wood.

(ii) *Eucalyptus crebra* and *Eucalyptus salmonophloia*.—Macroscopic and microscopic studies of truewood samples of a number of coloured woods of the genus *Eucalyptus*(9) have revealed that the woods of narrow-leaved ironbark (*E. crebra*) and salmon gum (*E. salmonophloia*) are in some instances difficult to separate by such examinations. Chemical studies have been undertaken in order to afford some definite means of separating these two woods, and, in view of Simpson's observations on the unusually high manganese content of salmon gum(6), determinations of manganese in truewood samples of these two woods were made. In ten samples of *E. crebra*, the manganese content varied from 0.94 to 3.05 mgms. of Mn_3O_4 per 100 grams of oven-dried wood (or from 0.3 to 2.1 per cent. of the ash). In the twelve samples of *E. salmonophloia* examined, the manganese content was found to vary from 2.59 to 40.2 mgms. (or from 0.5 to 6.6 per cent. of the ash). In each species, all samples were obtained from butt logs of different trees. Although the results showed that the manganese content was not a reliable diagnostic feature, they served to indicate the extensive variation that may be expected in a species, and hence the danger of quoting results based on the examination of too few samples. Most of the ashes of *E. salmonophloia* samples contained less than 1 per cent. of Mn_3O_4 , and except for two cases, i.e., 6.6 and 4.4 per cent., the manganese content of this wood was not unusually large.

(iii) *Occurrence in other Eucalypts*.—The closely related woods of the ironbarks, *E. sideroxylon*, *E. siderophloia*, *E. crebra*, *E. paniculata*, and *E. fergusonii*, and of the grey gums *E. propinqua* and *E. punctata* have been studied by means of a standardized qualitative procedure with the object of indicating any unusual occurrence of one of the elements generally found in wood. Manganese has been shown to be present in all these woods; to a small extent in the woods of *E. sideroxylon*, *E. siderophloia*, *E. crebra*, and *E. paniculata*, to a somewhat greater extent in the woods of *E. propinqua* and *E. punctata*, and to a still greater extent in the wood of *E. fergusonii*. At a later date it is proposed to examine these woods quantitatively with the object of using the determination as an aid to identification.

3. Procedure Employed for the Determination of Manganese.

The determination of manganese was carried out in duplicate in the following manner:—Five to 10 grams. of oven-dried wood splinters (amount depending on the species) were weighed accurately into a platinum dish. The wood was ignited for one hour at about 600°C., the position of the duplicate samples in the muffle furnace being reversed at the end of the half-hour in order to ensure a uniform air supply. The ash was cooled in a desiccator, moistened with water, and a few drops of concentrated sulphuric acid, followed by 1-2 cc. of hydrofluoric acid, were added. The dish and its contents were heated, very cautiously at first, later more strongly, and finally the sulphuric acid was fumed off. This treatment was repeated, care being taken not to

continue heating after fuming had stopped, as the more difficultly soluble oxides could be formed. The above process removed all silica, some of which has been shown to occlude manganese compounds(10).

Concentrated sulphuric acid (2.5 cc.), glacial phosphoric acid (0.5 cc.), and water (10 cc.) were then added, and the dish and its contents heated on a boiling water bath until all the material was dissolved. The whole was transferred to a 100 cc. beaker using sufficient water to have approximately 50 cc. of solution, i.e., 6 per cent. of acid present(11). Potassium periodate (0.3 gram.) was added, the solution boiled for 2 minutes and then heated on the boiling water bath for 20 to 30 minutes. After cooling, the solution was made up to 50 or 100 cc., depending on the colour obtained, and compared in the colorimeter with a standard solution of potassium permanganate prepared by the oxidation, in a similar manner, of manganese sulphate. Blank determinations were made on every occasion, but were entirely negative.

4. Summary of Results.

The study of samples of Tasmanian myrtle (*Nothofagus cunninghamii*) has revealed that, in any one tree, there exist differences in manganese content between sap and intermediate wood on the one hand, and truewood on the other. These differences are not constant for the species, e.g., in two trees the manganese content of the sapwood of one may not be very different from the content of the truewood of the other. This indicates an irregular occurrence of the element, but it may be stated that manganese can occur in fairly large quantities in this timber.

A similar irregular occurrence was observed in the case of some samples of salmon gum (*E. salmonophloia*), but in most cases the content could be described as a normal quantity. If the irregular occurrence of manganese in these species is typical, the possibilities of using the determination of the element as a diagnostic feature are very remote. The examination of Australian timbers to date has supported the statement that manganese is of universal occurrence in timber.

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Compression Wood in Hoop and Bunya Pine.

By H. E. Dadswell, M.Sc., and I. Langlands, B.E.E.*

1. Introduction.

In the work of the Division of Forest Products on the better utilization of Australian timbers, a recent problem connected with blind rollers made from hoop pine (*Araucaria cunninghamii*) and bunya pine (*Araucaria bidwillii*) is of general interest. A number of these rollers, which were mainly 39 to 42 inches in length, and 15-16 inch in diameter, showed a definite bend or spring sufficient to render them unfit for service; such faults developing after the articles have been manufactured form a definite source of loss to the manufacturer, and this loss is sufficient to prevent competition with imported rollers. In order to reduce or eliminate this source of loss, the Division was requested by the manufacturer concerned to investigate the causes of such bending in the rollers.

The bend was found to be due to a greater longitudinal shrinkage of the wood on one side of the roller. There are several possible causes for this shrinkage, of which the following were considered the most probable under the circumstances:—

- (1) The presence of sloping grain. In a piece of wood with sloping grain, i.e., in a sample in which the grain does not run parallel to the long axis in all parts of the piece, there may be an apparent longitudinal shrinkage which is in reality a component of transverse shrinkage. When sloping grain is present to any extent in a board or stick which is subsequently dried, transverse shrinkage will exert an influence on the length of the piece, and bending will result if the sloping grain is localized on one side. In the case of a number of rollers examined, the bending was due to such a cause. If care is exercised in milling and manufacture, bad shrinkage effects due to sloping grain should be eliminated before the article is completed.
- (2) The presence of growth abnormalities in the wood. A common abnormality, which causes excessive longitudinal shrinkage, is known to saw-millers of the Northern Hemisphere as "compression" wood. The longitudinal shrinkage (i.e., shrinkage along the grain) of normal wood is comparatively small, and ranges from 0.1 to 0.3 per cent. when the timber is brought from a green state to the oven-dry state. However, cases have been observed in which the shrinkage along the grain was abnormally large—in one case up to 5.78 per cent.(1). These cases of abnormal shrinkage have been shown to be due to a peculiar type of wood called "compression" wood. Thus, if bands of "compression" wood were present on one side of a board, and drying occurred, one would naturally expect the longitudinal shrinkage to manifest itself, and to cause the bending of the board.

* Officers of the Division of Forest Products.

Some dark bands of wood were present in many of the rollers examined, and it was considered probable that these were indicative of "compression" wood. Before describing tests by which such impressions were confirmed, it will be advantageous to consider what is known of "compression" wood, its formation, and its properties.

2. Description of Compression Wood.

Australian timber users, in general, are not familiar with compression wood, although they have probably noticed the irregular and dense bands of wood in pines, spruce, hemlock, and redwood. The name given to these denser bands of abnormal wood has been based on the fact that they are found commonly on the lower or compression side of branches and leaning trees(2). Other names which refer to this abnormal wood are "rotholz" (redwood), "proud wood," "timber bind," and "hard grain." According to Burns(3), it is generally accompanied by eccentric growth, and this has been substantiated by observations on Northern Hemisphere conifers.

The formation of compression wood was explained in general by Burns(3) as being due to one or more of the following causes:—

- (1) The wind, which acts as a mechanical stimulus resulting in a compression on the leeward and a tension on the windward side, the tree forming its greatest growth as well as compression wood on the compression side.
- (2) Differences in illumination on north and south sides.
- (3) Differences in branching, and hence better nutrition on the branched side.
- (4) Gravity acting as a stimulus.

Experiments in which compression wood was artificially produced in small trees were carried out by Burns, and as a result its production was considered to be a response to gravitational stimulus.

Büsgen(4) states that in cases of artificial production by the bending of branches or stems, the concave side of the bend is compressed, the convex side is under tensile strain, and the pressure acts as a stimulus to the formation of compression wood. The same stimulus is also considered to be the cause of its formation on the compression side of trees exposed to the wind. However, in a leaning tree, the formation of compression wood is generally ascribed to gravitational stimulus, and this could account for its presence on the underside of branches and leaning stems.

While its occurrence is fairly common in softwoods or coniferous woods, i.e., the spruces, firs, pines, hemlocks, and other species of the Northern Hemisphere, the same type of structure has not been reported for the hardwoods (oaks, ashes, hickories, eucalypts, &c.). Although up to the present it has not been reported, abnormal growth of the same nature as "compression" wood does occur in the trees of Australian coniferous species. For this reason, a brief *résumé* of the known properties of compression wood is given below, and this necessarily refers to observations made on coniferous timbers of the Northern Hemisphere.

The most outstanding property of compression wood is its tendency to shrink along the grain to a much greater extent than normal wood, thus causing bowing, splitting, and twisting in boards containing it.

On an end section of a log or board, it is generally recognizable by the rather wide growth rings containing a large proportion of dense late wood which is darker in colour. This greater width of growth rings, in comparison to that of normal wood, is accompanied by eccentric growth. That is to say, on the compression side of the log, the distance from pith to bark is greater than on the other side. This is demonstrated in Fig. 1.* Sometimes, there is no clear line of demarcation between compression wood and normal wood, and the two grade into each other imperceptibly. Thus, no fixed value for the longitudinal shrinkage of compression wood can be found, although, for species examined, it is greater than 0.3 per cent., and often as much as 1 per cent. and more.

The compression wood is generally much denser than the normal wood of the same growth ring, and in comparison with normal wood from the same tree, its mechanical properties are variable, even when allowance is made for the difference in density. It has been assumed that the wood formed in response to compression should be specially strong in compression, and that tension wood should similarly excel in tensile strength, yet various figures have appeared from time to time, which appear to show that this is not necessarily the case(5). The relative properties of normal wood and compression wood apparently differ greatly with the species, the property under consideration, the moisture content, and the severity of compression wood. As far as can be judged on available data, compression wood is deficient in modulus of elasticity, i.e., it has a low stiffness, in comparison with normal wood; even when higher in strength, it also shows a brittle fracture when tested in cross bending.

Under the microscope, there are several features which are indicative of compression wood. The cells are nearly circular in cross section in comparison with the typical rectangular or polygonal shape of the cells of normal wood, and in addition they are often separated by intercellular spaces instead of being completely joined one to another(6). Microscopical examination of longitudinal sections also reveals the presence of spiral checks or striations in the cell walls of the tracheids of the compression wood(6). Such spiral checks are not present in tracheid walls of normal wood.

While the amount of softwood timber containing compression wood is a considerable proportion of the total amount milled in America, that causing serious trouble in utilization is readily recognizable(2). It is thus eliminated as far as possible in building construction, or in other places where its excessive longitudinal shrinkage may cause trouble (such as in the bowing or sagging of beams, in bending, splitting, and twisting of boards, or in any product where the use requirements are exacting).

3. Compression Wood in Australian Timbers.

While the Division of Forest Products has not yet made a definite survey of the occurrence of compression wood in Australian pines, it has been recognized that it may be fairly common. For instance, certain boards of hoop pine are known to spring right out of the drying stacks; others twist and warp in drying; and others develop a pronounced bow. These characteristics in softwoods are typical of timber containing

* See Plate I. facing page 124.

compression wood. It is also known that millers express a preference for hoop pine logs from straight trees growing in flat sheltered areas, while the timber from trees growing on hillsides is disliked. They have no reason for such preference, except that the timber behaves better in milling and drying. Logs from certain hillside trees often show eccentric or off-centre growth, and timber from these logs misbehaves badly during milling and drying.

It is apparent, therefore, that many products made from Australian "pines" may contain compression wood, and this is likely to cause trouble in those products in which requirements are exacting. Thus, in the case of the blind rollers, where straightness is essential, many were found to be bent owing to the presence of bands of compression wood. This was recognizable macroscopically on the longitudinal face, although it was not easy to distinguish on the cross section, owing to the small area available for examination. A microscopic examination of the dark-coloured bands of wood definitely confirmed the opinion that it was compression wood, as the cells on the cross section were circular in shape, intercellular spaces were common (see Fig. 2), and spiral checks were observed in the cell walls of the tracheids (see Figs. 3 and 4). The longitudinal shrinkage of the dark band of wood was also determined, and found to average 1.5 per cent. in comparison with approximately 0.1 per cent. shrinkage for normal wood.

It is of interest to note that a blind slat of New Zealand white pine examined by the Division also showed a definite bend, due to the presence on one side of a distinct band of compression wood, which was darker in colour than the normal wood in the same slat. Here, again, microscopical examination revealed the typical characteristics of compression wood, the line of demarcation between normal and compression wood being very marked, while the longitudinal shrinkage of the compression wood was much greater than that of the normal wood.

A piece of hoop pine 4 inches x 4 inches in cross section, which was received from New South Wales for experimental purposes, showed a definite band of compression wood, approximately $1\frac{1}{2}$ inch in width on the quarter face. This had caused a distinct bend in the length of the piece, due to greater longitudinal shrinkage. In Fig. 5, the general appearance of this band of compression wood on a freshly cut cross section is shown. In this sample, there was abundant material for several comparative tests. The *basic density* of samples from both compression wood and normal wood was determined according to standard procedure (on basis of oven-dry weight in grams and volume in c.c. when soaked to maximum volume) with the following results:—

Normal wood—

Basic Density.

Average of five determinations on wood from different areas	26.8 lb./cu. ft.
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Compression wood—

Average of two determinations on wood from different areas	35.5 lb./cu. ft.
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The compression wood was, therefore, 1.33 times as dense as the normal from the same stick. The basic density of the normal wood was within the recorded range for samples of this species, namely, 26-34 lb./cu. ft. (average 29 lb./cu. ft.).

The toughness of sticks taken from both normal and compression wood was determined according to standard procedure. Four sticks of each kind of wood were tested, the average moisture content of each stick being 15 per cent. The toughness of the compression wood was higher (40 inch-lb./cu. in.) than that of the normal wood (28 inch-lb./cu. in.), but was not as high as would be expected from its greater density(7). Each of the four sticks of compression wood showed a distinct brittle failure in comparison with the more splintering failure of the normal wood. The greater longitudinal shrinkage of the compression wood was also demonstrated.

4. Conclusions.

From the few tests carried out, it is apparent that the compression wood found in Australian "pines" is similar in appearance, properties, and structural characteristics to that of the softwoods of the Northern Hemisphere. Thus, it is well for timber users to take note of its existence, and of its characteristic properties. For many purposes, its presence does not seriously affect the timber, but for any application in which requirements are exacting, it should be eliminated. This can best be done by careful selection. It is preferable to examine the freshly cut cross sections of logs, and to determine as far as possible the extent of compression wood, if any, in these logs. When milling for special products, the areas containing compression wood can be avoided, but boards which contain such wood need not be considered waste, as slightly bowed or twisted pieces are quite satisfactory for many uses.

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PLATE I.

FIG. 1.—A cross section of a spruce log showing eccentric growth and bands of compression wood—the dark wide bands on the lower side.



Manual for the Inspection of Aircraft Wood and Glue for the U.S. Navy, p. 20].

FIG. 2.—A cross section of *Araucaria bidwilli* (Bunya Pine) magnified 100 times—the upper cells are thick-walled, rounded in shape and in many cases separated from each other by intercellular spaces which can be readily seen, these features are typical of compression wood—the lower cells are more typical of normal wood, being large and angular in shape.

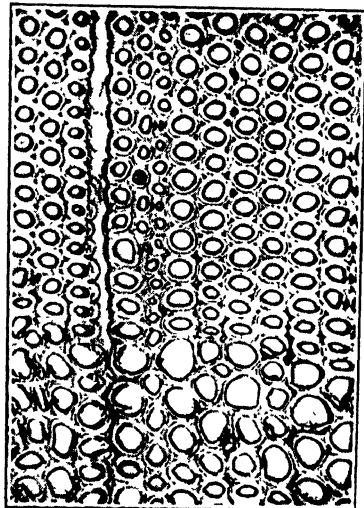


PLATE II.

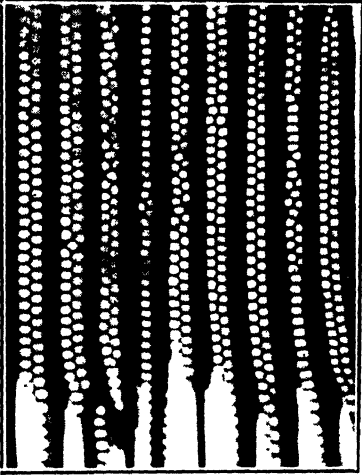


FIG. 3.—A radial section of *Araucaria bidwilli* (Bunya Pine) normal pine wood, showing arrangement of pits. 100 × cf. Fig. 4.

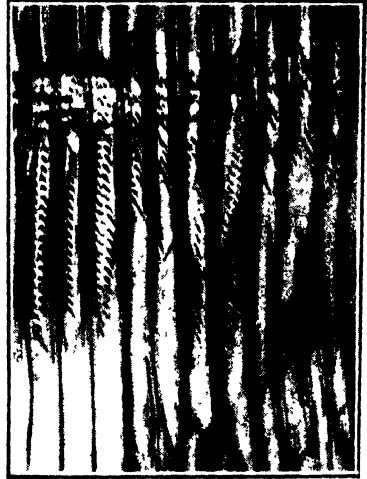


FIG. 4.—A radial section of *Araucaria bidwilli* (Bunya Pine) showing spiral checks in cell wall radiating from the pits—these checks are not common in normal wood (cf. Fig. 3) and are characteristic of compression wood. 100 ×.

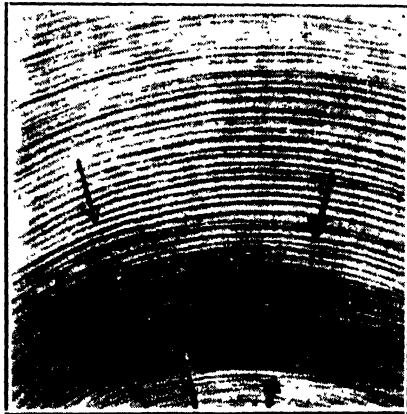


FIG. 5.—A cross section of a block of *Araucaria cunninghamii* (Hoop Pine)—one-half natural size—showing dark band of compression wood in contrast with normal wood.

NOTES.

Requests for Publications by Predecessors of the Council.

From time to time the Council for Scientific and Industrial Research is asked for copies of the various publications of the two bodies, namely, the Advisory Council of Science and Industry and the Institute of Science and Industry, which preceded it. Unfortunately, a number of these publications are out of print, and it is thus quite impossible for the Council to meet these requests.

Sometimes, too, requests are received from important libraries which are desirous of maintaining their sets of Council publications complete and which occasionally find that such sets lack a number or two. For instance, the Fisher Library of the University of Sydney is very desirous of having a copy of Bulletin No. 6—"Power Alcohol: Proposals for its Production and Utilization in Australia," issued in 1918.

In a country of such large distances as Australia, it is obviously of importance to maintain the contents of the various libraries in as complete a form as possible. It has accordingly been thought that if the foregoing position were generally known, some people who possess back copies of the publications in question, and who have no further use for them, would be only too glad to let the Council have them for transmission in turn to libraries or other people who want them.

The publications which are particularly desired are the following:—

Bulletins Nos. 1 (cattle tick), 2 (worm nodules), 3 (alunite), 4 (Bendigo Goldfield, Part I.), 5 (wheat storage problems), 6 (power alcohol), 7 (agricultural research), 8 (Bendigo Goldfield, Part II.), 9 (ferro-alloys), 14 (Posidonia fibre), 18 (wheats), 20 (power alcohol), 21 (white ants), and 26 (wheats).

Memoir No. 1. "The Australian Environment (especially as Controlled by Rainfall)" by Griffith Taylor.

Publications of the Council.—The Method of Distribution.

It has recently become evident that a brief description of the way in which the Council's publications are distributed would be of some value.

The publications in question may be classified into the Annual Reports, Bulletins, Pamphlets, and the *Journal*. A number of all these are distributed on a general mailing list which includes important libraries and scientific organizations not only in Australia, but throughout the world.

The main sources from which the Council's research information may be obtained are the Bulletins, Pamphlets, and the *Journal*. Each copy of the last-named being likely to contain articles of interest to different kinds of research workers, its distribution is fairly wide.

Each Bulletin and each Pamphlet, however, is confined to one subject, and any particular issue is thus of interest to one or two classes of research workers only. For that reason, both these series are distributed according to special lists. Thus, if an organization deals only with soils, it is sent only those Bulletins and Pamphlets which are likely to have a bearing on its work, and it is not sent those Bulletins and Pamphlets on other aspects of the Council's work, for example, forest products. Accordingly, some organizations and individual recipients would by no means have complete sets of these two series. On the back of the cover of each individual number, however, a complete list of the series issued to date is given. If, therefore, any libraries, scientific organizations, or individuals find that they have missed particular numbers of interest to them, those numbers will be forwarded promptly if they care to acquaint the Council with their desire.

Finally, each copy of the *Journal* contains a brief review of the publications that have become available since the previous issue of the *Journal*. One of the objects of these reviews is that the daily and technical press may use them to acquaint the general public with what material is available.

A Simple Chemical Test for Separating the Woods of Hoop Pine (*Araucaria cunninghamii*) and Bunya Pine (*Araucaria bidwilli*).

(Contributed by W. E. Cohen, B.Sc., Division of Forest Products.)

In the timber industry, cases frequently occur where it is very desirable to have a ready means of distinguishing between two or more closely allied timbers. The separation of the woods of hoop pine and bunya pine is such a case. Although the trees of these two species are very different, the woods are very much alike in appearance and structure. In certain cases, it is claimed that bunya pine wood has a pinkish tinge, but, as this is not general, such an observation cannot be used as a distinguishing characteristic.

With the object of finding a simple distinguishing test, the Division of Forest Products has made a comprehensive study of the structural and chemical features of the two woods. Macroscopic and microscopic examinations have failed to reveal any constant structural differences. The chemical study has been confined to the examination of the aqueous and alcoholic extracts of the woods with the application of numerous simple chemical tests for sugars, acids, resins, &c. As the result of this work, the simple chemical test described below has been developed.

The test is applied to the aqueous extracts which are prepared as follows:—

Rasped samples of the woods are prepared and the material which passes through a 20-mesh sieve is used. Five grams of this material (if air dry) is placed in a flask fitted with a reflux condenser, and extracted for two or three hours, at the temperature of a boiling water bath, with 50 cc. of water. After filtering and pressing the residual

wood, the latter is washed with 50 cc. of boiling water, the wash being added to the original extract. When cool, the volume of the extract is adjusted to 100 cc.

To 2 cc. of the aqueous extract, contained in a roomy test tube, 1 cc. of concentrated sulphuric acid is added to form a layer. The layers are mixed by gently shaking the test tube.

In the case of bunya pine, a pink colour will develop immediately, and an orange (harvest) coloured precipitate will form (sometimes slowly). With hoop pine, there will be no immediate colour change, but later a white gelatinous precipitate will form.

The observation of the pink colour has been found to be more reliable than that of the subsequent precipitate. In many cases the aqueous extracts of bunya pine are more deeply coloured (light orange) than those of hoop pine. Although this cannot be claimed to constitute another test, it can generally be used to give a fairly reliable indication. Naturally, in such cases, the pink colour mentioned above will then be orange pink. The test has been found to give the above differences when applied to 21 out of 22 samples of bunya pine and to 26 samples of hoop pine, all from individual trees. The defaulting bunya pine sample resembled hoop pine in many ways, and its origin is being further investigated.

An additional test which may be used in most cases, for confirmatory purposes only, is applicable to the alcoholic extracts prepared in a manner similar to that already described for the aqueous extracts. The procedure is as follows:—

To 2 cc. of the alcoholic extract, contained in a roomy test tube, add five drops of diphenylamine solution (20 per cent. alcoholic) and then 2 cc. of concentrated sulphuric acid to form a layer. Mix the layers by carefully shaking the test tube for about one minute, and then examine the resultant colour.

With bunya pine extract, the colour will be reddish brown. With hoop pine extract, the resultant colour will be light orange.

This test has given the above differences when applied to 21 out of 22 samples of bunya pine (the defaulting sample being the one already mentioned) and to 23 out of 26 samples of hoop pine. Hence, in most cases, it could be used as a confirmatory test, but the results obtained should not be permitted to reverse the deductions which have been drawn already from the test applied to the aqueous extract.

The Greenhouse White-fly in Tasmania.

The Greenhouse White-fly, *Trialeurodes vaporariorum*, is a serious pest in hot-houses in Tasmania, and particularly affects the growing of early tomatoes. Chemical treatment of this pest is difficult, and it has for some time been recognized that the best way to deal with it is by means of biological control.

In England, the tropical parasite *Encarsia formosa* has been found to be quite successful in hot-houses which are kept warm throughout the winter months. This parasite is a tiny Chalcid wasp, very susceptible to cold. It lays its eggs in the tests of the white-fly, which

turn black when parasitized, owing to the parasitic grub destroying the white-fly nymph under the test and then turning into a blackish pupa.

So far, all attempts to establish this parasite in lands south of the Equator have failed. Consignments carried in cool store are so weakened by the prolonged exposure to cold weather that they either arrive with every individual parasite dead, or, at best, they only yield a few weakly individuals from which it would be most unwise to attempt to rear a new generation.

The first consignment of *Encarsia* from England received from Mr. S. Garthside, who is an officer of the Council's Division of Economic Entomology, and who is working at Farnham Royal, arrived in Canberra in time for Dr. R. J. Tillyard to bring them to Launceston during a visit to Tasmania in January last. They were then placed in a special rearing cage under the charge of Mr. H. Turner, Horticulturist, Tasmanian Department of Agriculture. Only three or four weakly individuals emerged from the consignment over a period of one month from its reception, and none of these lived very long. Though this consignment was a failure, other methods will now be tried whereby the prospects of success will be much enhanced. With the co-operation of Mr. Turner and the tomato-growers of the Launceston district, it is hoped to establish this parasite in Tasmania during the coming spring or summer. It will be most important to make sure of a continuous supply of white-fly during the winter and early spring in the hot-houses.

Physiology of Wheat in Relation to Grain Filling.

A Note on the Literature.

In an article¹ in the last number of this *Journal*, on "The Physiological relations between Tillers of a Wheat Plant," it was indicated that the finding, that the glumes of wheat contribute less than 40 per cent. of the dry weight of the grain, was contrary to findings by Boonstra. The statement of Boonstra's results was quoted from an abstract. Since then a translation of his paper has been received from the Imperial Bureau of Plant Breeding, and this is found to modify the abstract. He states, without quoting figures, that "probably the glumes play a great part in the formation of the carbohydrates for the grains." He continues: "The assimilation of the leaves (lamina) in the last period (from flowering onwards) does not amount to more than ± 25 per cent. of the total grain weight." His findings therefore agree very closely with those of Smith, whose estimate of the proportion of grain weight supplied by the leaf blades was 25 and 22.5 per cent. in 1930 and 1931 respectively. Boonstra's work has been published in more detail elsewhere², but this paper, like the original of the one quoted, is not yet available in Australia.

1. Smith, H. F. This *Journal* 6: 32-42, 1933.

2. Boonstra, A. F. H. R., *Der Zuechter* 3: 345-52, 1931.

3. ———— Med. Landbouwhoogeschool, Wageningen, 33: (3), 1929.

Peg-Leg in Cattle.

In a previous note (this *Journal*, 5: 263, 1932), it was mentioned that one of the problems which the Research Station at Townsville is investigating is that of "peg-leg" of cattle. Mention was also made of the small field station for peg-leg studies that has been established at "Helenslee," near Charters Towers, as a result of the co-operation afforded by local cattle-owners.

The precise cause of peg-leg is still obscure, although there are indications that it is due to some deficiency, possibly phosphorus. The symptoms are emaciation, arthritis, fragile bones, arched vertebral column, hooked neck, and stiffness in the gait. Ultimately, the death of the animal ensues, and there is no doubt that peg-leg is responsible for considerable losses in North Queensland each year.

With a view to obtaining as much information as possible regarding the trouble as it occurs in the field, Mr. R. B. Kelley, B.V.Sc., the Field Officer attached to the Townsville Station, last year spent some time visiting various cattle stations in the affected areas. The paragraphs that follow are based on his observations. It should be mentioned, however, that his visit took place in a dry time, and after the country had suffered at least two dry years.

In general, the incidence of the condition was higher in the areas of poorer country (10 head per square mile), but in exceptionally dry times it is also found on better country (20 head per square mile). In parts, the trouble is of comparatively recent origin, as on one large station, of a carrying capacity varying from 10 to 20 or more head per square mile, it was not noticed until about the year 1924.

Due attention was paid by Mr. Kelley to yearly rainfalls and calving percentages, but owing to the extent of the runs (some are 2,000 square miles in extent) it was often quite impossible to estimate these percentages from the data available.

Further, the number of females is only approximately known, except in the year when bang-tail mustering occurs, and frequently this number includes heifers of low breeding age. The cows calve all the year round.

In places, it was evident that there was a vicious cycle—dry times and little feed, a calf at foot, and resultant low condition of the dam. These low-conditioned, wet cows merged into those showing all the signs of peg-leg, e.g., some arching of the back, concavity on the dorsal surface of the neck, and stiffness in the gait. If the calves are weaned at this stage, it is not uncommon for the cows to "hold their own" until the feed improved. In some cases, the cows even put on condition with the available food. If, however, they still suckle the calf, as they must, perforce, where weaning is impracticable (open herd conditions) the humped back and stiff gait become progressively more pronounced and typical cases of peg-leg result.

There was some evidence that young breeding cows showed the most mortality. Of the cows examined post-mortem, all those which were advanced cases of peg-leg proved not to be in calf. Their ovaries were relatively small in size; the Graafian follicles, though in cases multiple, were neither cystic nor was there one more advanced than the others. Mr. Kelley proceeds:—"As has been indicated, I have not, as yet, visited

a property where data were available from which to determine calving percentages, but the whole set-up of the cycle, dry feed, low condition, laziness (disinclination to breed) in the males, almost atrophic ovaries in those females which are advanced cases, leads me to think that the condition, or perhaps more correctly these conditions, do play an important part in decreasing the annual drop of calves."

In another case, Mr. Kelley reported:—"The area over which the cattle were spread, the mixed nature of the herd, and their uniformly low condition, made a numerical estimation of the incidence of peg-leg extremely difficult, but in one run of 40 miles through three watering areas, during which a representative sample of the herd should have been seen, I considered that the aged breeders were low in condition, and that 30 per cent. had peg-leg, while among cows $2\frac{1}{2}$ to 4 or 5 years of age, the incidence was 80 per cent. or 90 per cent. Cases of peg-leg were seen among 1930 and 1931 calves, and among the 1932 calves many appeared to be motherless and in very low condition."

Due attention was also paid to goats and indigenous animals. As regards the former, in places a peculiarity in the gait reminiscent of peg-leg was seen. For instance, goats when moving were noticed to have well-developed knee action, the carpus being distinctly flexed as the fore-leg was elevated, and as the upper arm was extended, the metacarpus was brought sharply out and in line with it before the hoof touched the ground—almost a goose-step action. Here again, however, the indications were that the condition was most prevalent in those animals subjected to the strain of reproduction, e.g., Mr. Kelley states:—"Three goats, all females, though in good condition (particularly the dry seven-year old goat killed, and the youngest goat, about eighteen months old, also dry) moved without this almost exaggerated knee action. The condition of the third goat was compatible with her period of lactation and her age, which was nine or ten years. The owner says that from time to time this gait has been noticed generally in the older goats."

One or two kangaroos were examined post-mortem, and once again there were indications—admittedly slight ones—that the animals were not unaffected through some deficiency. For instance, the difference in the ratio between the diameter of the medullary cavity of the tibia to that of its greatest outside diameter was marked in the two sexes. The annulus of bone in the adult male tibia appeared thicker and denser than that of the female. These differences may possibly be connected with a deficiency intensified in the case of the female by the strain of reproduction. A number of tibia were accordingly collected from males and females, the latter carrying young at various stages of development, and these will be examined in the laboratory at a later stage.

However, the grazing habits of kangaroos are vastly different from those of cattle. They are freely mobile, and by reason of the formation of their teeth, eschew long grass, and are found most frequently where the grass is green, short, and succulent. These selective grazing habits are reflected in the contents of their alimentary canals, which Mr. Kelley found uniformly much greener than those of the cattle found in the same paddocks. Seeing, as is well-known, that the mineral content of young grass is much higher than that of the older material, kangaroos would naturally not be subjected to such mineral starvation as would the cattle.

The Imperial Agricultural Bureaux.

The Executive Council of the Imperial Agricultural Bureaux has issued its third annual report (for 1931-32). It will be remembered that the creation of the bureaux was the outcome of the Imperial Agricultural Research Conference, 1927, which recommended the establishment of eight bureaux to collect, collate, and disseminate information on research in certain branches of agricultural science, and to assist workers in these branches to form contacts with other workers.

The Conference also recommended that each bureau should be located at an institution already well known for research in its particular branch, and that the cost of the bureaux should be met from a common fund formed by contributions from Empire Governments. The scheme was subsequently accepted by the Governments, and came into operation on the 1st April, 1929.

The following are particulars of the eight bureaux which have been established:—

Bureau.	Location.	Direction.	Australian Correspondent.
Animal Nutrition	Rowett Research Institute, Aberdeen	Dr. J. B. Orr; <i>Deputy</i> —Mr. H. Crow	Sir Charles Martin, Chief of Division of Animal Nutrition (C.S.I.R.), Adelaide
Animal Genetics	Animal Breeding Research Department, Edinburgh University	Professor F. E. Crow; <i>Deputy</i> —Dr. F. Fraser Darling	Dr. J. A. Gilruth, Chief of Division of Animal Health (C.S.I.R.), Melbourne
Fruit Production	East Malling Research Station	Mr. R. G. Hatton; <i>Deputy</i> —Mr. D. Akenhead	Dr. B. T. Dickson, Chief of Division of Plant Industry (C.S.I.R.), Canberra*
Soil Science ..	Rothamsted Experimental Station, Herts	Sir John Russell; <i>Deputy</i> —Mr. G. V. Jacks	Professor J. A. Prescott, Chief of Division of Soil Research (C.S.I.R.), Adelaide
Plant Genetics (Herbage Plants)	Welsh Plant Breeding Station, Aberystwyth	Professor R. G. Stapledon; <i>Deputy</i> —Dr. R. O. Whyte	Dr. B. T. Dickson, Chief of Division of Plant Industry (C.S.I.R.), Canberra
Plant Genetics (Plants other than Herbage)	Plant Breeding Institute, Cambridge	Sir Rowland Biffen; <i>Deputy</i> —Dr. P. S. Hudson	Dr. B. T. Dickson, Chief of Division of Plant Industry (C.S.I.R.), Canberra
Agricultural Parasitology	Institute of Agricultural Parasitology, St. Albans	Professor R. T. Leiper; <i>Deputy</i> —Dr. B. G. Peters	Dr. I. Clunies Ross, Parasitologist, Division of Animal Health (C.S.I.R.), Sydney
Animal Health ..	Veterinary Research Laboratory, Weybridge	Dr. W. H. Andrews; <i>Deputy</i> —Mr. W. A. Pool	Dr. J. A. Gilruth, Chief of Division of Animal Health (C.S.I.R.), Melbourne

* Deputy Correspondent, Mr. W. M. Carne, Senior Plant Pathologist, Division of Plant Industry (C.S.I.R.), Hobart.

The first year of the bureaux's existence was largely occupied in organization. In their second year, the presence in London of a number of scientific officers from the Empire overseas as advisers to

their Governments at the Imperial Conference, 1930, afforded an opportunity for discussions on the work of the bureaux. In the course of these discussions the scientific advisers urged those bureaux which had started abstracting journals to enlarge them and others which were contemplating them to start them forthwith.

The year 1931-32 was thus the first year in which practically all the bureaux have been issuing journals, and this work has occupied much of the attention of the bureaux's staffs. The journals issued are :—

1. *The Veterinary Bulletin*, issued monthly from Weybridge.
2. *List of Publications relating to Soils and Fertilizers*, issued monthly from Rothamsted.
3. *Plant Breeding Abstracts*, issued quarterly from Cambridge.
4. *Herbage Abstracts*, issued quarterly from Aberystwyth.
5. *Horticultural Abstracts*, issued quarterly from East Malling.
6. *Bulletin on Animal Genetics*, issued quarterly from Edinburgh.
7. *Nutrition Abstracts and Reviews*, issued quarterly from Aberdeen.

Abstracts on Agricultural Parasitology prepared by the Bureau at St. Albans appear by special arrangement in the *Quarterly Journal of Helminthology*, the Bureau obtaining reprints; in addition, that Bureau compiles and issues each year a list of the titles and sources of all papers appearing during the year on helminthology.

Each bureau has thus in its own field tackled the problem of providing research workers in the Empire with means of keeping informed and abreast of the developments throughout the world in their own subjects. Taken as a whole, the group covers a large part of the subjects which interest agricultural and veterinary workers. The successful issue of these abstracts, &c., marks a stage in the services which the bureaux are rendering to research workers in the Empire. In addition, satisfactory progress has been made in promoting contacts between research workers in the Empire, in collecting information on the various lines of research in progress in the Empire, in dealing with special inquiries, and in issuing bibliographies and reviews on subjects of special interest.

The Australian Dairy Cattle Research Association.

The Council for Scientific and Industrial Research is warmly supporting the action of a number of breeders of pure-bred dairy cattle, under the leadership of Dr. R. M. Kinross, of Sydney, in creating an Australian Dairy Cattle Research Association. In certain of the States, Branch Committees have been formed by the Association, and a Federal Council composed of delegates nominated by these State Committees has been set up with head-quarters in Sydney. The first meeting was held on 13th April.

The main object of the Association is to provide means to enable scientific investigations to be undertaken into the principal diseases affecting dairy herds in Australia. The two outstanding troubles are contagious abortion (Bang's disease) and contagious mastitis or mammitis. The Australian Dairy Council has shown its interest in the scheme by promising to provide £2,000 per annum for five years towards its estimated cost. The Directors of the Commonwealth Bank have voted a similar sum for two years from the Rural Credits Development Fund; while the Primary Producers Union of New South Wales has promised £100 per annum, with the probability that the sum will be increased later.

As a first step, co-operative arrangements have been made between the Research Association and the New South Wales Department of Agriculture for a thorough investigation into contagious abortion to be conducted at the Veterinary Research Institute at Glenfield. The State Department will provide certain facilities and staff, while further expenses, to an estimated total of £1,550 per annum, will be met by the Association. It is proposed that work on contagious mammitis shall be centred in Victoria, and a scheme drawn up by a special committee of the Australian Veterinary Association, and involving an expenditure of approximately £4,500 per annum for a period of years, has been approved by the Federal Council. It will not, however, be put into effect until the requisite money is in sight. The Victorian Department of Agriculture, the University of Melbourne, and the Council of Scientific and Industrial Research will all co-operate with the Australian Dairy Cattle Research Association in the mammitis work.

For the time being, the Research Association will limit itself to active participation in these two investigations, but later it hopes to extend its activities into other fields, particularly the investigation of tick fever and pleuro-pneumonia, in close association with the Animal Health Research Station at Townsville.

Electrical Moisture Meters for Timber—Third Series of Correction Figures.

In Trade Circular No. 9 of the Division of Forest Products, descriptions were given of different types of electrical moisture meters. At the present time, the most common type of these instruments in Australia is the "blinker sorter," and appended to the Trade Circular was a table showing the corrections necessary when using such an instrument on timbers other than that for which it has been set. Similar figures for other species were obtained later, and these were published in the *Journal of the Council for Scientific and Industrial Research*, November, 1932, as a second appendix (Division of Forest Products, Reprint No. 9) to the Trade Circular. Further tests on still different species have now added to this information. The first of the following two tables contains correction figures of a similar nature to those previously published.

Recently, a number of multi-reading blinkers have been placed in commercial use, and it is evident that, despite these being somewhat more expensive, there is a demand for them in addition to the sorter type of instrument. To enable the multi-reading blinker to be used on different Australian species, correction figures are being determined over the full range of moisture contents covered by these instruments. The results so far obtained are given in the second of the two following tables. It is advised that these two tables should be inserted after Appendices I. and II. in Trade Circular No. 9.

APPENDIX III. (TRADE CIRCULAR No. 9).

Corrections Used with Blinker Sorters for Different Species of Timber.

For moisture contents in the neighbourhood of 12 to 15 per cent.

Species.			
Botanical Name	Common Name		
<i>Doryphora sassafras</i>	New South Wales sassafras	0	
<i>Endiandra</i> sp.	Maplum	0	
<i>Eucalyptus rostrata</i>	Red gum	+2	
<i>Schizomeria ovalis</i>	Crabapple	+1	
<i>Sloanea woollsi</i>	Yellow bean	+1	

Corrections used with Multi-point Electrical Moisture Meters for different Species of Timber.

Meter Reading	Per Cent. Moisture	7	8	9	10	11	12	13	14	15
Species.	Common Name.	Correction.								
<i>Pseudotsuga taxifolia</i> ..	Douglas fir ..	0	0	0	0	0	0	0	0	0
<i>Acacia melanoxylon</i> ..	Blackwood ..	+3	+3	+3	+2½	+2½	+2	+2	+1½	+1½
<i>Endiandra palmerstoni</i> ..	Queensland walnut	-2	-2	-1½	-1½	-1	-	-½	-½	+1
<i>Eucalyptus diversicolor</i> ..	Karri ..	+1	+1	+1	+1	+½	+½	+½	0	-½
<i>Eucalyptus marginata</i> ..	Jarraah ..	+½	+½	+½	+½	+½	+1	+1	+1	+½
<i>Eucalyptus obliqua</i> ..	Messmate ..	0	0	0	0	0	0	0	+½	+½
<i>Eucalyptus regnans</i> ..	Mountain ash ..	+1	+1	+1	+1	+1	+1	+1½	+1½	+1½
<i>Eucalyptus rostrata</i> ..	Red gum ..	+2	+2	+2	+2	+2	+2	+2	+2	+2
<i>Nothofagus cunninghamii</i> ..	Myrtle (red) ..	+2	+2	+2	+2	+2	+2	+1½	+1½	+1½
	Myrtle (white) ..	+1½	+1½	+1½	+1	+1	+1	+½	+½	+½
Meter Reading	Per Cent. Moisture	16	17	18	19	20	21	22	23	24
Species	Common Name	Correction								
<i>Pseudotsuga taxifolia</i> ..	Douglas fir ..	0	0	0	0	0	0	0	0	0
<i>Acacia melanoxylon</i> ..	Blackwood ..	+1	+½	0	-½	-½	-1	-1	-1½	-1½
<i>Endiandra palmerstoni</i> ..	Queensland walnut	+½	+2½	-13	+3½	+4	+4	+4½	+½	..
<i>Eucalyptus diversicolor</i> ..	Karri ..	-1	-1	-1	-1½	-1½	-1½	-1½	+1½	-1½
<i>Eucalyptus marginata</i> ..	Jarraah ..	+1½	+1½	+1½	+2	+2	+2	+2	+2	+2
<i>Eucalyptus obliqua</i> ..	Messmate ..	+½	+1	+1	+1½	+1½	+1½	+1½	+2	+2
<i>Eucalyptus regnans</i> ..	Mountain ash ..	+1½	+1½	+2	+2	+2	+2	+2	+2	+2
<i>Eucalyptus rostrata</i> ..	Red gum ..	+2	+2	+2	+2	+2	+2	+2	+2	+2
<i>Nothofagus cunninghamii</i> ..	Myrtle (red) ..	+1½	+1	+1	+½	+½	0	-½	-½	-1
	Myrtle (white) ..	0	0	-½	-½	-1	-1½	-1½	-2	-2½

Recent Publications of the Council.

Since the last issue of this *Journal*, the following Bulletins and Pamphlets of the Council have been published:—

Bulletin No. 72.—"Varieties of Wheat in Australia: A Catalogue with Pedigree or Source, and a Genealogical Chart showing the Relationships of the more Important Varieties," by J. R. A. McMillan, M.Sc.

The writer of this Bulletin is the Senior Plant Geneticist of the Division of Plant Industry. In 1929, when, in pursuance of the programme of investigations of the Division, plans were being prepared as to the wheat crosses which should be made in order to study the mode of inheritance of certain characteristics, it was realized that it was very desirable to have, in a readily available form, the pedigree of each variety of wheat that had been grown in Australia. Accordingly, all available literature was searched and the information therefrom compiled. The compilation was then sent to the State Departments of Agriculture, with a request that they examine it critically, correct any errors, and add any further information available. This they did, and the value of the catalogue has accordingly been considerably enhanced. The pedigree of some 1,000 varieties of wheat have been given, and a genealogical chart of common Australian wheats is included as a folder at the back.

Bulletin No. 73.—"A Soil Survey of the Nyah, Tresco, Tresco West, Kangaroo Lake (Vic.), and Goodnight, N.S.W.) Settlements," by J. K. Taylor, B.A., M.Sc., F. Penman, M.Sc., T. J. Marshall, B.Sc.(Agr.), and G. W. Leeper, M.Sc.

The Bulletin gives the results of soil surveys that have been carried out on five settlements in the region of the Murray Valley, aggregating 9,300 acres, mainly planted to horticultural crops. Considerable decreases in cropped areas have recently occurred on one settlement (Tresco), and a proportion of each has been rendered unproductive by an excessive increase in soil salinity. Six soils belonging to five types have been defined. The soil position on the settlements has been outlined, mentioning the distribution and extent of the several soils, irrigation and drainage necessities, the importance of soil salinity, and its sphere of influence on each area. A general discussion of the problems connected with the soils of the areas is also given from the aspects of horticultural development, climatic influence on crops, improvements of soils and possible increase in yield, irrigation and drainage requirements, and soil salinity.

Pamphlet No. 37.—"The Sheep Blowfly Problem in Australia," Report No. 1, by the Joint Blowfly Committee.

This comprehensive report of 136 pages plus plates was briefly reviewed on page 62 of the previous issue. Copies are obtainable (price 1s. 6d., post free) on application to the Council or to the New South Wales Department of Agriculture.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. .—"Observations on Soil Moisture and Water Tables in an Irrigated Soil at Griffith, New South Wales," by E. S. West, B.Sc., M.S.

Pamphlet No. .—"The Occurrence of *Anaplasma marginale* Theiler 1910, in Northern Queensland," by J. Legg, D.V.Sc.

Pamphlet No. .—"The Grading of Western Australian Timbers: Report on, and Suggested Specifications for, the Grading of Jarrah and Karri based on Investigations in 1932," by F. Gregson, B.E., and R. F. Turnbull, B.E.

Pamphlet No. .—"Meteorological Data for Various Localities in Australia" (in co-operation with the Commonwealth Weather Bureau).

In addition, the typescripts of future publications dealing with the buffalo-fly, squirter in bananas, and lucerne flea are approaching completion.

Journal of the Council for Scientific and Industrial Research.

Vol. 6.

AUGUST, 1933.

No. 3.

Botulism of Sheep in Western Australia and its Association with Sarcophagia.

By *H. W. Bennetts, D.V.Sc.**

The report that follows deals with work forming part of a programme of investigations which the Council and the Western Australian Department of Agriculture have been carrying out in co-operation. Dr. Bennetts has been seconded to the Council from the Department, and the latter provides laboratory accommodation, an experimental field station, travelling facilities, &c.—ED.

Summary.

1. Botulism of sheep was first recorded in Western Australia in 1928. Since then, the annual incidence has progressively increased. This disease is now regarded as being a source of greater economic loss than all other diseases affecting sheep in Western Australia. It is due to the ingestion of toxic rabbit carrion.

2. The high incidence in Western Australia, as compared with that recorded in other parts of Australia, is ascribed to the annual long dry period extending over many months. The great increase in the rabbit population, combined with the attempted destruction by poisoning, results in abundant carrion being available during this period when depravity of appetite is acute.

3. It is suggested that the term "sarcophagia" is appropriate for the condition described, and that further work should be undertaken to determine the actual cause and means of prevention of this condition.

4. The clinical features of the disease are described.

5. *B. paratubulinus* has been isolated from rabbit carrion.

1. Introduction.

Botulism in cattle has been of frequent occurrence in Western Australia for a number of years. An accurate description of the syndrome was recorded departmentally as early as 1896. The nature of the disease was not definitely determined until 1922, when Seddon confirmed Filmer's clinical diagnosis by isolating *B. paratubulinus* from bones forwarded from a property in the Great Southern district.

* Senior Veterinary Research Officer, C.S.I.R., seconded from the Western Australian Department of Agriculture.

Horses, not uncommonly, are affected with a condition which on clinical grounds alone appears to be botulism.

Botulism in sheep has been deemed the cause of a very heavy annual mortality, and indeed to be the source of greater economic loss than all other diseases. This is quite contrary to the general Australian experience. It has been recorded in only one other State—that of New South Wales—where it does not seem to be common. Seddon (4) refers to one outbreak in 1925 which resulted from ingestion of rabbit carcasses, and later (5) stated that bone-chewing “may on occasion be exhibited by sheep”; Rose and Edgar (3) recorded a similar mortality in 1929 where 20 sheep died out of a flock of 400. In the last instance, *B. botulinus* type B was isolated from the rabbit carrion. Seddon and Carne (6) had obtained it previously from a similar source.

The organism responsible in Western Australia would appear to be *B. paratubulinus*, which is now recorded here as having been isolated from rabbit carrion. In 1928, toxicogenic saprophytes were isolated from the femur of a sheep, which had died from this disease, and from rabbit carrion, but they were never typed out.

The remarkable incidence in this State is evidently due to conditions which are peculiar to it, and a more detailed account than that given in the first record (Bennetts (1)) will not be without interest.

2. Nature of the Disease.

(i) *History*.—The disease was first recognized in January, 1928, when the owner of a property in the Merredin district reported that his sheep were dying from what he considered to be braxy-like disease. The writer investigated and diagnosed the condition as botulism, as the result of the examination of three animals. In a flock of approximately 400 depastured on wheat stubble, a number of sheep were observed to be eagerly eating rabbit carrion dug out of a warren that had been fumigated with carbon bisulphide several months previously. Fifteen sheep died. The diagnosis was confirmed by the isolation of a toxicogenic saprophyte from the femur of a sheep dead for some weeks. Towards the latter part of the same summer, similar outbreaks, following ingestion of poisoned (phosphorus) rabbits' flesh were investigated in other centres of the wheat belt.

It has been established that the disease appeared sporadically during 1927, but no evidence has been obtainable that serious losses were experienced prior to 1928. Since then, judging by reports, it has become progressively more widespread, and the serious mortalities occurring annually throughout the wheat belt are causing considerable concern at the present time.

(ii) *Distribution and Economic Importance*.—The disease is now known to occur practically throughout the whole of the sheep-carrying portion of the South-western Division of the State. It occurs generally as widely-separated outbreaks except in the Eastern Wheat Belt, where, over a large area of country, very heavy losses are experienced annually. The death rate is said to be as high as 50 per cent. in some flocks.

(iii) *Incidence*.—From information available, the annual incidence is steadily increasing. There is a very definite seasonal incidence from January to May. With the advent of green feed following the winter rains, the disease disappears. There is no evidence that sex, breed, or age affect the incidence. Our own observations indicate, however, that it is usually the best-grown and best-conditioned sheep in the flock which become affected.

(iv) *Clinical Description*.—Usually, the period between the onset of symptoms and death is one to two days. Affected animals occasionally linger for several days and, rarely, recovery takes place. The syndrome is typically botulinic. The initial sign is a spasmodic wriggling of the tail as though fly-blown. Later, the animal shows a stiff gait and a disinclination to move, and becomes separated from the flock. It progresses for only short distances, and then lies down in a position of sternal decubitus. Appetite is lost and rumination suppressed. The head is held in a drooped position, and there is frequently a more or less profuse flow of saliva, with sometimes protrusion of the tongue. Constipation is usual. Paralysis of the hind limbs becomes marked, and finally the animal is unable to rise. Respiration becomes spasmodic and abdominal, the intercostal muscles not functioning. Death takes place quietly in the position of normal decubitus.

(v) *Post-mortem Appearances*.—There are no gross pathological changes. The gall bladder is distended with bile, and the large bowel is frequently packed with hard, dry ingesta. Remnants of rabbit carcasses, though often difficult to recognize, may be found in the rumen and reticulum.

(vi) *Etiological Factors*.—The condition appears to be invariably associated with ingestion of rabbit carrion. The main factors responsible for the serious incidence of the disease are believed to be two—the unusually long dry period, which is of normal occurrence, resulting in a reduced phosphorus content of pastures and other dietetic deficiencies (including protein), and the rabbit pest, which, through measures taken to cope with it, means numerous decaying carcasses.

Seasonal and Dietetic.—The seasonal conditions differ from those found in other parts of Australia. In the South-western Division, there are, broadly speaking, two seasons—a period of reliable and adequate rainfall with green pasture, extending over four to five months from May or June until September, and alternating with a period of seven to eight months, when little or no rain falls and the herbage is dry; then, unless supplements, mineral and other, are fed, sheep tend to exhibit a depraved appetite. This is manifested in a relish for rabbit droppings* and rabbit carrion in all stages of decomposition. On occasions, sheep have been seen, when driven around the paddock, to continue chewing carcasses which they had picked up before being disturbed. On one property, green lucerne, rabbit carcasses, and mounds of rabbit droppings were all exposed to a mob of sheep in which mortality had been occurring: they showed a decided preference for the droppings, which they ate quite eagerly—the lucerne proving relatively unattractive.

* It appears distinctly unlikely that rabbit faeces would provide a suitable medium for the growth and toxin production of *B. parbotulinus* so that ingestion would tend to botulism. However, the possibility should be considered pending experimental evidence.

As a result of Theiler's well-known work on lambsiekte in South Africa, as well as Australian observations, it is generally accepted that osteophagia results from phosphorus deficiency in the diet. Western Australia, except for a few small areas, is markedly phosphorus deficient. The following table (7) shows P_2O_5 content of soil in two widely-separated areas where the disease occurs.

TABLE 1.

District.	Soil.	
	Total P_2O_5 , Per cent.	Available P_2O_5 , Per cent.
<i>Merredin—</i>		
Location 1 (0"-9")	0.022	0.009
(9"-18")	0.024	..
Location 2 (0"-9")	0.022	0.005
(9"-18")	0.015	..
<i>Chapman—</i>		
Location 1 (0"-9")	0.036	0.009
(9"-18")	0.048	..
Location 2 (0"-9")	0.019	0.006
(9"-18")	0.030	..

The figures for available phosphorus appear to be rather high. Teakle (8) found an almost complete absence of water soluble phosphate from Merredin and other wheat belt soils. Unfortunately, we have no available figures for dry "pasture" in the affected area. The P_2O_5 content of a sample of dry pasture from a property where sheep eat rabbit droppings, but on which botulism is not known to occur, was 0.147 per cent. Analyses of pasture from other areas in the State indicate, as elsewhere, that even where the phosphorus content is relatively high in the green feed, it falls very considerably in the corresponding dry feed. It appears evident that the effect of low phosphorus content of soil is secondary to the dominant influence of the long dry period.

Throughout the Eastern Wheat Belt, the general practice is to run sheep on wheat stubbles or fallow paddocks during the dry period, and towards the end of the summer little feed is left other than dry innutritious grasses and wheat straw. Two samples of wheat stubble from Merredin analysed by Dr. Underwood* were found to contain 0.06 and 0.07 per cent. P_2O_5 , and were probably deficient in most other requirements. In these districts generally, no provision is made for supplementary feeding of sheep during this period. In the Great Southern District, however, which is primarily a sheep-raising area, oats are grown extensively, and supplementary feeding with chaff, oats, linseed "nuts," &c., is resorted to. In these circumstances, depraved appetites are not noted, and botulism is rarely encountered in sheep, although in cattle, osteophagia and botulism are by no means uncommon throughout. Rabbits are not so numerous there, and the comparative paucity of rabbit carrion may be a factor, but it is not of major importance.

* Animal Nutrition Officer of the Western Australian Department of Agriculture.

Carrion eating by sheep, which may be termed "sarcophagia"—it can hardly be described as osteophagia—is usually ascribed to phosphate deficiency, and preventive measures recommended accordingly. They have not been an unqualified success in Western Australia, and it is becoming evident that phosphorus deficiency is not alone responsible for the depraved appetite exhibited. It is rather remarkable that Wheat Belt sheep are notable locally for being large framed. Their growth is naturally much more rapid during the period when green feed is available, but the growth limiting effect of acute phosphorus deficiency reported in South Africa is not noted, nor have any gross bone changes been observed.

Rabbits.—The rabbit population has multiplied enormously during the last six to seven years, particularly throughout the Wheat Belt areas. Rabbit poisoning is compulsory. During the early dry months of the year, phosphorus baits are extensively laid, and dams are often fenced off and cyanided water provided for the rabbits. As a result, during the late summer and autumn months when the depraved appetites of the sheep have become acute, large numbers of rabbit carcasses are distributed over the countryside. Even if cleaning up of carcasses is attempted, it is difficult to remove them all from the stubbles, and sometimes losses have been experienced as a result of rabbits dying on properties other than those on which they had been poisoned, the owners being at the time ignorant of their existence.

Rose and Edgar, in New South Wales, have adduced some evidence indicating that the infection of carrion with *B. botulinus* probably took place from the intestinal tract of the rabbits and not from the adjacent soil. Field evidence here also suggests that rabbits carry the organism responsible (in this case apparently *B. paratuberculosis*) as a normal bowel inhabitant, and thus assist in distributing the organism. It is otherwise hard to explain the rapid spread of the disease, particularly to country which is lightly stocked and much of which has only been cultivated or stocked for upwards of five years. Rabbits, when abundant, also probably contribute towards a greater incidence of the disease by eating out much of the best feed.

The low price of wheat for the past few years has resulted in a decreased use of superphosphates, and the financial depression has led to an increase in rabbit population owing to a relaxation in the offensive against them. These factors may have contributed towards the greatly increased incidence of the disease during the past three or four years.

3. Prevention.

Following the diagnosis of the disease in 1928, the feeding of phosphates was advocated as a preventive of the depraved appetite which resulted in carrion eating. A lick composed of bone meal and salt in equal parts was recommended and the results obtained were reported to be satisfactory. It was considered, however, that this procedure was uneconomic owing to the high cost of bone meal, and the Department of Agriculture has recommended licks containing mineral phosphate. Since 1932, a lick composed of di-calcic phosphate, molasses, and salt (18 per cent. P_2O_5) has been in general use. These mineral licks have not always proved palatable, and frequently it has been necessary to add crushed oats, or to increase the percentage of salt or of molasses, until

sheep become accustomed to them. Undiluted lick is then taken quite readily. Sheep on one property consumed 4 oz. per head per week during the latter part of the dry period. In this case, botulism, which had been enzootic prior to the use of licks, disappeared, but the results obtained generally in the prevention of carrion eating have not been entirely satisfactory.

In some instances, failure has evidently been due to the following factors:—

- (a) Consumption of inadequate quantities of lick.
- (b) Too great delay in the provision of lick. When once the depraved appetite is developed, sheep definitely prefer carrion to licks containing mineral phosphates, or even bone meal.
- (c) The use of unsuitable licks. Despite extensive propaganda, proprietary and other licks containing totally inadequate amounts of phosphate have been used alone, or in conjunction with those advised.

Phosphorus deficiency alone may not be entirely responsible for the depraved appetite which manifests itself in carrion eating. There is sufficient evidence to warrant a more systematic and exhaustive collection of field data than are at present available. This should be accompanied by appropriate chemical investigation and experimental work. A protein deficiency suggests itself as being possibly contributory to the depraved appetite exhibited by sheep on dry pasture, and Filmer (2) has recommended oats as a summer feed for sheep, as they supply both phosphorus and some protein. He also points out that they may be used with the prescribed licks in order to solve the question of palatability in a convenient and economical manner. That this would greatly minimize the losses from botulism is indicated by the comparative immunity of the Great Southern District where the provision of oats alone appears to prevent the occurrence of depraved appetite.

It has been suggested that preventive inoculation with anaculture would be a more economical way of dealing with the difficulty under present conditions, and experimental work is projected.

The collection and proper disposal of all rabbit carrion is of course recommended, but the difficulties are obvious.

4. The Isolation of *B. paratuberculosis* from Rabbit Carrion.

As already stated, toxicogenic saprophytes originally isolated from rabbit carrion and a sheep bone were not typed.

Further material was examined this year with the object of determining the organism responsible for the botulinic syndrome in sheep, and, after two unsuccessful attempts, a toxicogenic saprophyte has been isolated, and by means of toxin-antitoxin tests determined to be *B. paratuberculosis*. In May last, rabbit carcasses were received from a property in the Northam district, where 120 sheep had died out of a flock of 1,100 being grazed on wheat stubble. The cause of death was diagnosed as botulism.

Method of Isolation.—The rabbit carrion was in various stages of decomposition. Some was moist and contained maggots, but the majority was quite dry, and practically skin, fur, and bones. Portions

of dried bone, muscle, and semi-decomposed muscle from four carcasses were minced with due precautions to prevent further contamination. "V-F" broth under vaseline, containing a little finely-divided sheep's heart, was seeded with 28 grammes of the material and incubated for ten days at 35 deg. C. Examination of the culture showed that at least four anaerobes were present. An endeavour is being made to isolate the toxicogenic organism in pure culture.

A guinea pig drenched with 2 c.c. of the culture fluid developed the syndrome which is characteristic of botulism in guinea pigs, i.e., vomition, paralysis, aphonia, loss of weight, &c., and died within 24 hours. A second guinea pig to which minced carrion had been fed at the rate of 5 grammes per day for five days, died from botulism on the sixth day.

Serological Tests.—Mr. Graham Edgar, of the Veterinary Research Station, Glenfield, kindly supplied the following antisera:—*B. botulinus* type A, type C, a polyvalent A, B, C, and *B. paratobotulinus*. Toxin-antitoxin tests were carried out with these, with centrifuged culture and with culture filtrates.

A preliminary test, in which guinea pigs were inoculated with mixtures of 1 c.c. of supernatant fluid from centrifuged culture and equal amounts of each of the various antisera, indicated that the toxin present was that of *B. botulinus* type C, this being the only serum which gave complete protection. This finding was not borne out by subsequent tests, which are given in detail, and apparently resulted from the fact that the type C serum was the only one which was sufficiently potent to protect against the excessive amounts of toxin given.

On the 5th May, a Seitz filtrate of the culture (now fifteen days old) was made and tested for sterility. Chloroform was added as a preservative, and the toxin stored in the ice box. The minimum lethal dose of this toxin for a 250-300 gm. guinea pig was found to be 0.025 c.c.

The toxin was diluted with normal saline, and appropriate mixtures of this and the various antisera were made and incubated for one hour at 37 deg. C. The mixtures were then inoculated intramuscularly into guinea pigs, each receiving 2 c.c. The results are given in Table 2:—

TABLE 2.

Guinea Pig No.	Inoculation.	Result.
10	{ 6 M.L.D. toxin	Dead 3 days
11	{ + 1 c.c. <i>B. botulinus</i> type A antiserum	Dead 2 days
12	{ 6 M.L.D. toxin	Survived
13	{ + 1 c.c. <i>B. paratobotulinus</i> antiserum	"
14	{ 6 M.L.D. toxin	"
15	{ + 1 c.c. <i>B. botulinus</i> polyvalent type A, B, C antiserum	"
16	{ 6 M.L.D. toxin	"
17	{ + 1 c.c. <i>B. botulinus</i> type C antiserum	"
18	{ Controls	Dead 3 days
19	{ 6 M.L.D. toxin	Dead 2 days

The toxin is neutralized by both *B. botulinus* type C and *B. parabotulinus* antisera (also by polyvalent serum containing type C antibodies) and is therefore that of *B. parabotulinus* which is known to be neutralized by type C as well as by its homologous serum, type C toxin being neutralized only by its homologous serum.

To obtain confirmation of this result, in view of the contradictory finding in the preliminary test with unfiltered toxin, a further test was carried out in which mice were substituted on account of shortage of guinea pigs. The M.L.D. of the filtered toxin for a 30 gm. mouse was found to be 0.01 c.c. The toxin-antitoxin experiment, the results of which are tabulated in Table 3, was carried out in a comparable manner to the previous test. The amount of inoculum in each case was 1 c.c. given intramuscularly.

TABLE 3.

Mouse No.	Inoculation.	Result.
6	{ 5 L.M.D. toxin	Died 1 day
7	{ + 0.5 c.c. <i>B. botulinus</i> type A antiserum	"
8	{ 5 M.L.D. toxin	Survived
9	{ + 0.5 c.c. <i>B. botulinus</i> type A, B, C antiserum	"
10	{ 5 M.L.D. toxin	"
11	{ 0.5 c.c. <i>B. botulinus</i> type C antiserum	"
12	{ 5 M.L.D. toxin	"
13	{ + 0.5 c.c. <i>B. parabotulinus</i> antiserum	"
14	{ Controls	Died 1 day
15	{ 5 M.L.D. toxin	"

This test confirmed the previous one. The organism isolated is therefore *B. parabotulinus*.

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Thrips Investigation.

I. The Seasonal Fluctuations in Numbers of *Thrips imaginis* Bagnall and Associated Blossom Thrips.

By J. W. Evans, M.A.*

(From the Waite Agricultural Research Institute, University of Adelaide.)

The occurrence of thrips in plague numbers throughout the southern areas of Australia has been recorded at intervals during the past 25 years. *Thrips imaginis*, which inhabits flowers and blossom, is the important species concerned. These infestations occur in spring and early summer, and are associated with a marked reduction of the apple crop in these years. As a result of these losses, thrips play a part in influencing the State-wide fluctuation of the apple crop, a problem of great importance to the industry.

An investigation of thrips, in this respect, has been undertaken as a co-operative enterprise between the Council, the Waite Agricultural Research Institute (University of Adelaide), certain State Departments of Agriculture, and the Thrips Investigation League, and has been placed under the direction of the Chief Entomologist at the Waite Institute, Dr. J. Davidson (see page 216). The Thrips Investigation League is a body that was set up by fruit-growers, merchants, and others concerned in the fruit industry soon after the disastrous thrips year of 1931. Its objects are to stimulate the investigation of the thrips problem, and to collect funds to supplement those made available by research organizations studying that problem.

The present paper by Mr. Evans deals with the results of observations, obtained during the past year, on one aspect of the problem.—En.

Summary.

A study is being made of the seasonal fluctuations in numbers of *Thrips imaginis*, and associated blossom thrips, in the neighbourhood of Adelaide. A summary of the data obtained during a complete year from April, 1932—March, 1933, is presented. Throughout the year, daily records have been made of counts of the thrips populations of roses. During the spring, additional daily records were obtained of the thrips populations of other blossom. The purpose of this aspect of the investigation is the determination of the factors responsible for thrips infestations, by means of the correlation of the rises and falls of the populations with meteorological conditions.

A method by which the periods of generations of *Thrips imaginis* during any season can be calculated from data concerned with the development of the insect at different temperatures is given in an Appendix.

1. Introduction.

In order to obtain definite information regarding the factors responsible for thrips infestations, a study is being made of the seasonal fluctuations of natural populations of blossom thrips in the neighbourhood of Adelaide. This work will be carried on continuously during the course of the investigations. The data presented here comprise the results of the first year's observations from April, 1932—March, 1933 inclusive.

* An officer of the Council's Division of Economic Entomology, attached to the Waite Institute in connexion with the Thrips Investigation.

2. Sampling Technique.

Records of thrips populations are made in the following manner:—Samples of flowers from a plant are cut directly into a cylindrical cardboard box, which is closed with a tightly fitting lid. The box is taken into the laboratory, and its contents emptied into a large glass cylinder. This* has an open bottom, which rests on a sheet of paper, a perforated zinc tray inside, on which the blossom rests, and a close-fitting lid having a cotton wool pad in the centre. The outside of the cylinder is covered with black paper, from the top to the level of the tray. Before the flowers are put in, a few drops of turpentine are placed on the cotton wool, and an electric light, with the bulb close to the bottom of the jar, is turned on. About half-an-hour after the flowers have been put into the cylinder, the great majority of the thrips that were in them are found dead on the paper, only a few remaining in the blossom. The insects are transferred with a camel-hair brush to a small dish of dilute alcohol, separated into species, sexes, adults, and nymphs, and each group counted. The locality, date, and amount of blossom from the host plant are then recorded, together with details of the thrips population. In addition to scattered observations made in various localities during the year, several consecutive series were made during the spring, and one consecutive series has been carried on during the whole year. In all, nearly a thousand separate records have been kept.

3. Population Records.

(a) Rose Series.

Since the beginning of April, 1932, sample counts have been taken of the thrips populations of roses growing in a garden adjacent to the Waite Institute. For eight and a half months of this period, twenty roses at the same stage of development were picked daily from one of three hedges of Cecil Brunner roses growing in this garden, and their thrips inhabitants were recorded. For three and a half months during the winter, these roses were not available, and from 7th July until 23rd August, the samples were taken from such scattered roses of various varieties as were present in the garden. Towards the end of August, a bush of *Fortuniana* roses came into flower, and from the 26th of this month until 31st October, records were regularly taken from it. *Thrips imaginis* was the only species present in every sample; the others in order of persistence were *Haplothrips victoriensis* Bagnall, *Isoneurothrips australis* Bagnall, *Thrips tabaci* Lind, and *Frankliniella insularis* Franklin. Six other species occurred occasionally in small numbers, the most prevalent being *Physothrips kellyanus* Bagnall, in winter and spring, and *Desmothrips davidsoni* Morison, during the summer.

Apart from *imaginis*, the species mentioned above play no appreciable part in outbreaks, but their fluctuations in numbers are being followed for comparative purposes, and to add to our knowledge of thrips in general. Although the method of sampling may remain standardized throughout the season, the number and kind of flowers in the locality under observation are changing all the time. Therefore, samples of host plants examined for the purpose of determining the seasonal

* Being described in the *Bull. Entom. Res.*, 24: 1938.

fluctuations in the numbers of any species cannot contain a constant proportion of the available numbers in any selected locality. It is, however, believed that, in the case of *imaginis* and *victoriensis*, the numbers recorded in roses represent a fair sample of the adult population, as these species prefer roses to other flowers. Roses are not the favorite food plant of *tabaci*, *australis*, and *insularis*. Therefore, these species are represented in counts from roses only when they are distributed generally in very large numbers. Ageratum, carnations, and chrysanthemums are among the favoured hosts of *tabaci*; myrtles and eucalypts of *australis*; and carnations, scabious, and geraniums of *insularis*. Hence a sudden influx of any of these species of thrips into roses need not necessarily signify the emergence of a brood; it may equally mean that some nearby chrysanthemums, carnations, or myrtles have finished flowering, and that their thrips inhabitants have accordingly been forced to seek such other food as is available. Conversely, the absence of these species from roses is no indication that there are no thrips about at the time, as it is generally possible to find small numbers of all the three species referred to above in their principal host plants, during any month of the year.

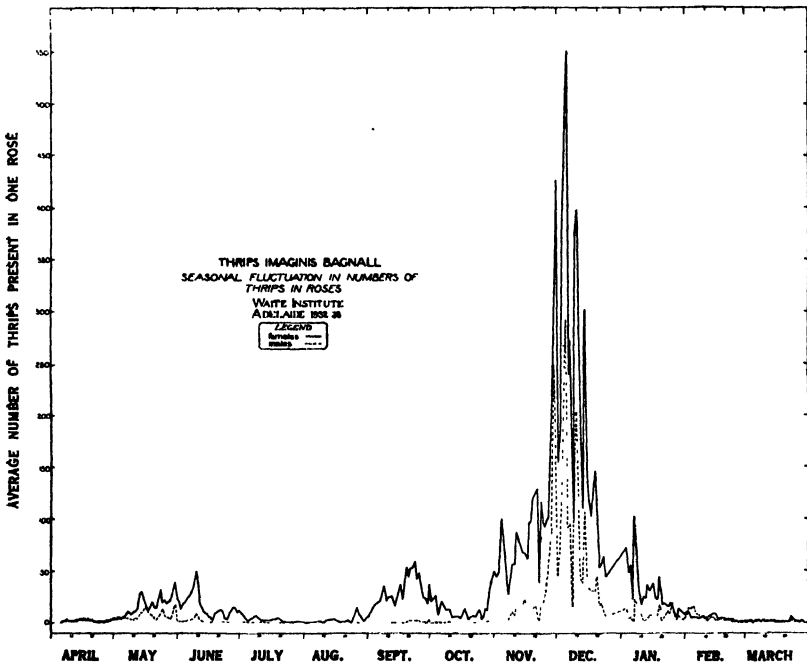


FIG. 1. Showing the seasonal fluctuation in thrips in roses at the Waite Institute, 1932-33.

Figure 1 represents the average daily numbers of male and female *Thrips imaginis* in one rose, over a period of twelve consecutive months. The chart is constructed from 274 daily records. The numbers of nymphs found have not been plotted, as roses are evidently not favorable breeding sites. Possibly the hardness of the calyces and flower stalks prevents the insertion of the insect's ovipositor.

The chart gives an accurate picture of the fluctuations of generations, with the exception of the latter half of October, when the *Fortuniana* roses were past their prime and few in number. Other records made at this time indicate the second spring generation emerged two weeks earlier than is shown in the chart. In a previous publication,* attention was drawn to the fact that, during the autumn, the weather resembles that of spring, and that these two periods afford optimum conditions for the increase of thrips. That the conditions during April were more favorable for reproduction than in March is shown in Fig. 1 by the rise in numbers in May. (In March, the average mean daily temperature was 20° C., and 160 points of rain fell. In April, the average mean daily temperature was 15.2° C., and 550 points of rain fell.) The three waves of increasing emergence in May are followed by a further increase in June. This is succeeded by a drop during July and August. At the end of the latter month, and during September, the emergence of the first spring generation took place. During October, the numbers dropped on account of the cold weather, and it was not until November and December that any considerable increase occurred. The numbers again fell in December, reaching a low level, which was maintained until the end of the period under consideration.

The sex ratio did not remain constant throughout the year. In April, the sexes were approximately equal. In May, the females outnumbered the males, and again, to a greater extent, in June and July. The spring emergence was almost entirely composed of females. In November, the proportion of males increased, and from December until the end of March the sexes were approximately equal.

Two types of parthenogenesis have been shown to occur among thrips; (a) thelytokous parthenogenesis, in which eggs from unfertilized females give rise only to female offspring, as with *T. tabaci* in the neighbourhood of Adelaide, where males have not been found; (b) arrhenotokous parthenogenesis, in which eggs from unfertilized females give rise only to males (fertilized eggs produce only females). A third type has been recorded by Raymond† with *Physopus pallipennis* Uzel, in which thelytokous parthenogenetic generations alternate with sexual generations.

Thrips imaginis belongs to the second type. The first autumn generation appeared in May, and was the progeny of the relatively small numbers of thrips living in April. It was closely followed by the second generation which emerged in June. The male line followed the female line during both generations, but at a progressively lower level (Fig. 1). The majority of the eggs laid by females of the first generation must have been fertilized, and hence gave rise to a preponderance of females.

There is no true resting stage, merely a delayed development during the winter, the spring emergence being composed of offspring of the second autumn generation. In the autumn, the males started from stock composed of approximately equal numbers of the sexes, and the proportion of males to females steadily decreased. In the spring, the proportion of males increased, following on a generation consisting largely of females, until once more, in the summer, a balance was established between the sexes.

* Council for Scientific and Industrial Research, Pamphlet 30, 1932.

† Raymond, G. "Contributions à l'étude des Thrips attaquant les oeillets." *Ann. Soc. Linn. Lyon* 52: 1923.

For the purpose of this paper, the length of a generation is defined as the period required for the complete development of an individual from the time the egg is laid until the resulting adult lays eggs. Those individuals that reach adult stage during this period of time are considered as comprising a generation. In the Adelaide district, where low winter temperatures are seldom recorded, eggs may be laid and development continue throughout the year, so that actually there is a succession of generations. (The average mean daily temperature for June and July, for the last eight years, recorded at the Waite Institute is 10.9°C.)

For convenience, a generation may be considered as commencing on a date where a marked increase in the numbers of thrips (the result of favorable meteorological conditions), follows a period of a relatively stable though small population. Commencing with this selected date, the duration of a generation can be calculated approximately. One method of doing this is discussed in the Appendix to this paper. The beginning of a new generation may also be determined from analysis of samples of the population, since a change in the relative abundance of the sexes, or a sudden rise in numbers, indicates a new generation.

(b) Cape Weed and Salvation Jane Series.

In order to follow the progress of the thrips population during the spring, and to serve as checks on the counts made from roses during this critical period of the year, daily counts were made of thrips present in the flowers of Salvation Jane (*Echium plantagineum*), and Cape weed (*Cryptostemma calandulaceum*), both introduced weeds known to be attractive to thrips. With both species, 50 flowers were picked every morning from the centre of large patches of the weeds growing near the Waite Institute. The numbers of thrips in the samples indicate only approximately the populations present at any time, since the numbers of blossoms present in the area did not remain constant. The thrips increased to a maximum at the middle of the period of flowering, and then decreased. It might be supposed that counts taken when the flowers were beginning to fail would show a disproportionately high number of thrips, the available numbers being crowded into a reduced quantity of blossoms. It is probable, however, that a reduction in blossom produces a corresponding reduction of the attractiveness of the area of weed for thrips, so that the two factors may balance each other.

The charts (Figs. 2, 4, and 5) serve to demarcate the generations, and illustrate the effect of increasing temperatures in shortening the length of the generations.

(i) *Cape Weed Series*.—Fig. 2 represents the progress of the population of *Thrips imaginis* in Cape weed flowers. It comprises two complete generations, the first commencing on 26th August and ending on 8th October, the second emerging on 10th October and lasting until 4th November. The drop in numbers after the latter date is due to the food plant dying out with the onset of dry weather. The two generations can be separated by the relatively greater height of the male line after 10th October.

In a previous publication, it was suggested that one of the causes to which thrips outbreaks may be ascribed is the alternation of very hot days with cold days in the spring, the hot days having the effect of

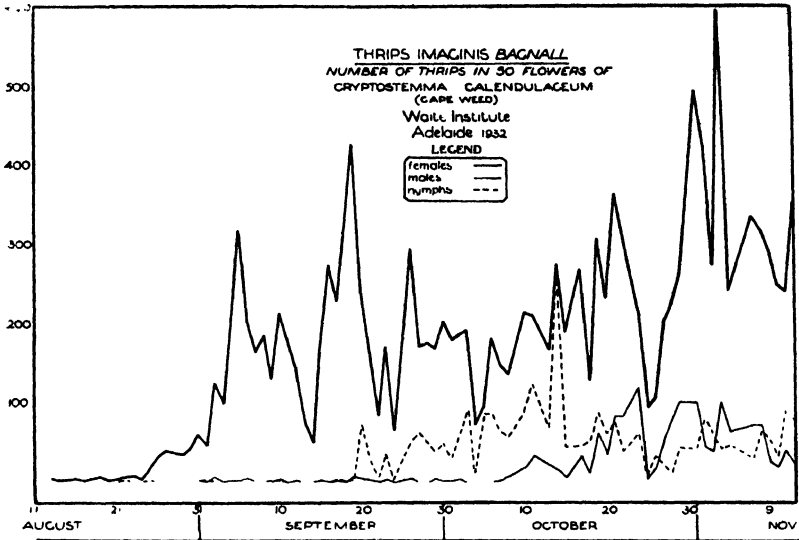


FIG. 2. Showing the numbers of thrips in 50 flowers of Cape Weed in various months.

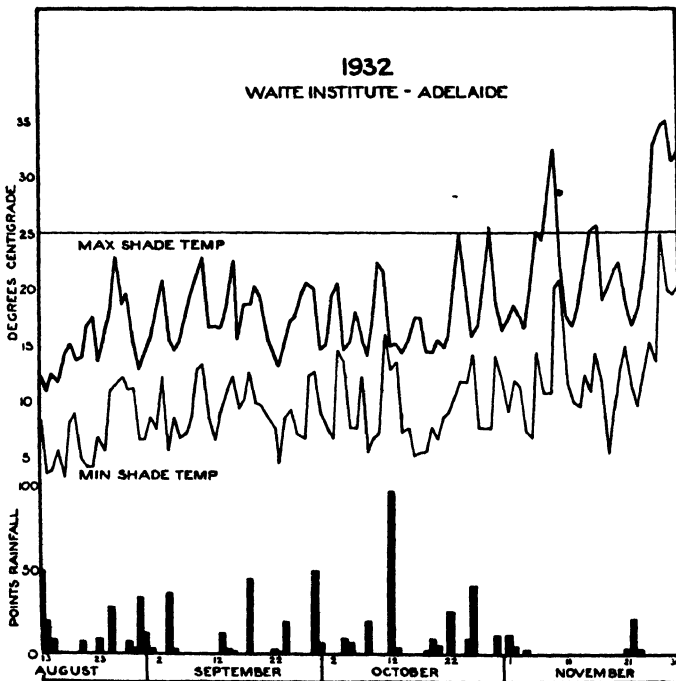


FIG. 3. Chart showing the meteorological conditions during the observations of thrips populations.

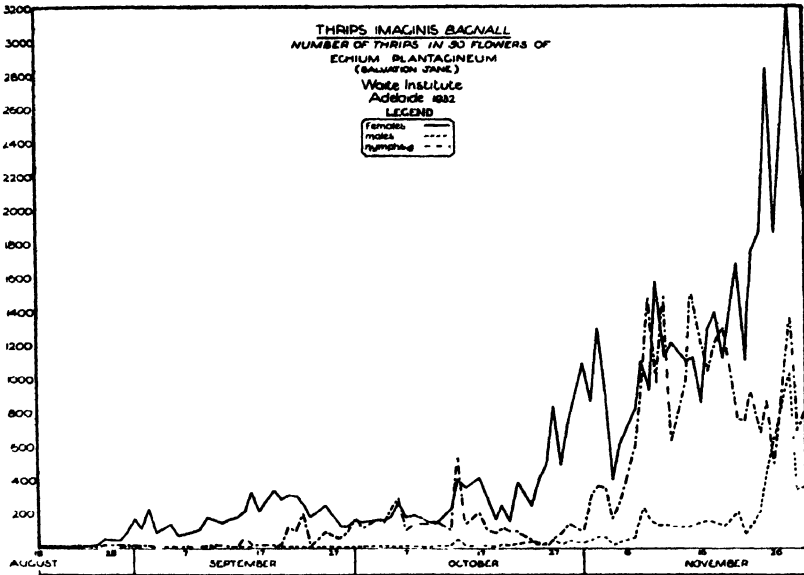


FIG. 4. Showing the number of thrips in 50 flowers of Salvation Jane in various months.

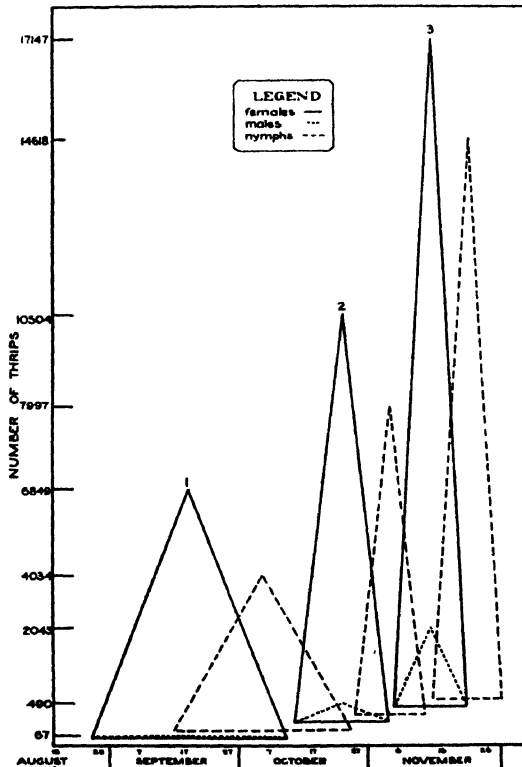


FIG. 5. Analysis of the data presented in Fig. 4. (For explanation see text.)

bringing up together large collections of individuals which otherwise would have emerged on separate days. Figure 2 shows clearly how several separate waves of emergence may follow each other consecutively over a long period when the weather is cool. A few hot days early in September would have had the effect of producing less waves, but much bigger ones. The result of this synchronization would show up in succeeding generations.

Three separate waves will be noticed in the first generation. In the second generation, the first wave is distinct, being separated from the succeeding ones by a deep depression between 21st and 31st October, which can be correlated with the depression between 5th September and 16th September, and is not the direct result of prevailing weather conditions. By comparing Fig. 2 with the meteorological conditions (Fig. 3), it will be seen that the extremes of temperatures are not correlated with rises or falls in the numbers of thrips. This correlation is not evident until a succession of days of high temperature (above 25° C.) have brought about an overlapping of waves or generations, so that large numbers of individuals emerge directly the temperatures rises to a sufficiently high point.

(ii) *Salvation Jane Series*.—Fig. 4, representing the spring population of *Thrips imaginis* in Salvation Jane flowers, comprises three complete generations and the commencement of a fourth. (Three of these generations are represented in a diagram, drawn to scale—Fig. 5.) The fourth generation, being incomplete, is omitted. The height of each triangle represents the total number of thrips, whether males, females, or nymphs, that were found in the samples during the period of the generation involved. The base line represents the duration of the generations. It will be noticed in Table I. that the progeny of each generation consists of less individuals than its forbears and its resulting adults. This is explained by the fact that, although a large proportion of the nymphs on a plant of Salvation Jane congregate on the flowers, numbers also feed on other parts of the plant, wherever shelter is obtainable. The adults, on the other hand, concentrate on the flowers.

(c) Other Records.

In addition to the series of records presented in the preceding paragraphs, other series were obtained. These will be useful for comparison with similar records for other seasons, and for determination of the plants in which the first spring generations of *T. imaginis* can multiply prior to the blossoming of apple trees. A summary of the data obtained is given in Table II. *T. imaginis* was present in all the samples recorded below. Entries have been made in the last column of the table only if this species was scarce (less than an average of one insect to every two flowers), when the series commenced.

With the assistance of orchardists at Kersbrook and Balhannah, records were kept of the thrips populations infesting the principal varieties of apples grown in these districts. In both localities, 50 blossoms (approximately) were picked at random from each variety in flower at the time, and posted to the laboratory, where the thrips were isolated, sorted, and counted. The samples were taken twice a week. No difference was noted in the relative attractiveness to thrips of the different varieties.

TABLE I.—NUMBERS OF *T. imaginis* IN THE FLOWERS OF SALVATION JANE DURING THE GENERATION PERIODS GIVEN IN COLUMN 2, AND METEOROLOGICAL DATA FOR THE CORRESPONDING PERIODS.

Generations.	Length of Generations.	Total Rainfall in Inches.	No. of Days Rain Fell.	Mean Daily Average Temperature (° C.).	Total Population.
1	27.8.32–11.10.32	2·8	34	13·1°	67 ♂ 6,849 ♀
Nymphs	15.9.32–26.10.32	2·2	30	11·1°	4,034
2	12.10.32–4.11.32	2·3	16	13·9°	490 ♂ 10,504 ♀
Nymphs	27.10.32–12.11.32	·3	7	17·1°	7,997
3	5.11.32–22.11.32	·2	16	17·9°	2,046 ♂ 17,147 ♀
Nymphs	13.11.32–30.11.32	·3	7	21·2°	14,618
4	23.11.32–	·1	3	26·3°	3,229 ♂ 16,201 ♀

TABLE II.—SUMMARY OF POPULATION RECORDS OF *T. imaginis*, MADE IN THE SPRING OF 1932, PRIOR TO OCTOBER.

Blossom	Locality.	Samples Taken		No of Samples.	Nymphs first Recorded	Increase in Nos. first Recorded.
		From—	To—			
Almond ..	Adelaide	15th July	1st Sept.	24	1st Sept.	29th Aug.
<i>Prunus</i> ..	"	9th Aug.	9th Sept.	15	9th Sept.	26th Aug.
<i>Pissardii</i>	"					
<i>Prunus Mume</i>	"	11th Aug.	25th Aug.	8	..	22nd Aug.
Plum ..	"	29th Aug.	28th Sept.	17	16th Sept.	..
Pear ..	"	21st Sept.	10th Oct.	9	30th Sept.	..
<i>Acacia</i> spp.	"	2nd Aug.	19th Sept.	4	14th Sept.	14th Sept.
Plum ..	Blackwood	1st Aug.	19th Sept.	17	12th Sept.	7th Sept.
Cherry ..	"	12th Sept.	11th Oct.	5	11th Oct.	..
Apricot ..	"	11th Sept.	14th Sept.	3	..	12th Sept.
Pear ..	"	24th Aug.	11th Oct.	9	19th Sept.	12th Sept.
<i>Acacia</i> ..	"	16th Aug.	1st Sept.	3	1st Sept.	1st Sept.
<i>normalis</i>	"					
<i>A. pycnantha</i>	"	24th Aug.	10th Sept.	4	10th Sept.	..
<i>A. armata</i>	"	24th Aug.	10th Sept.	4	..	..
<i>A. obliqua</i>	"	24th Aug.	10th Sept.	5	..	Never abundant
<i>A. cultiformis</i>	"	1st Sept.	..	1	1st Sept.	..
<i>A. sophora</i>	"	1st Sept.	..	1	1st Sept.	..

The data presented in Table III. are given to show the small thrips populations present in apple blossom during the past spring. The orchard at Balhannah suffered severely from infestations during the 1926 and 1931 season.

TABLE III.—AVERAGE NUMBER OF *Thrips imaginis* IN ONE APPLE BLOSSOM, AND QUANTITY OF BLOSSOM EXAMINED, OCTOBER-NOVEMBER, 1932.

Balhannah.			Kersbrook.		
Date.	No. of Thrips per Blossom.	No. of Blossoms Examined.	Date.	No. of Thrips per Blossom.	No. of Blossoms Examined.
4th October ..	0.3	155	3rd October ..	0.7	137
6th October ..	0.45	193	6th October ..	1.5	170
7th October ..	0.4	49	.. ..	..	..
11th October ..	2.25	289	10th October ..	1.0	219
14th October ..	0.9	290	14th October ..	2.1	324
17th October ..	2.3	275	.. ..	..	..
19th October ..	1.5	39	19th October ..	2.6	374
20th October ..	0.4	297	21st October ..	1.6	323
24th October ..	0.9	294	24th October ..	9.8	467
27th October ..	2.6	294	.. ..	..	..
31st October ..	3.6	198	31st October ..	14.0	286
3rd November ..	2.9	63	3rd November ..	11.8	89

4. Discussion.

The main purpose of this paper is to put on record certain observations made during the course of the investigation in 1932-33. When similar data have been accumulated over a longer period, an attempt will be made to analyse fully the information thus obtained.

The records enable one to correlate fluctuations in thrips populations with meteorological conditions. It is evident that the important factors regulating their numbers, and hence the occurrence of plague infestations, are the weather conditions prior to, and during, an infestation.

The control exerted by parasites or predators, at any time, or in any place, appears to be of so little account as to be of no more than of academic interest.

That the meteorological conditions responsible for outbreaks are not small local departures from the normal, but climatic variations on a big scale, is evident from the fact that outbreaks of thrips occur at the same time over immense areas of Eastern and Western Australia. In these areas, the outbreaks may vary in intensity in different places, due to such factors as elevation, hence greater rainfall, or to a profusion or lack of breeding sites.

It is the opinion of the writer that the numbers of individuals comprising the first spring generation determine the possibilities of a subsequent infestation. The numbers present in this generation are dependent especially on the meteorological conditions during the preceding four months.

An examination of the meteorological data for past years has shown that thrips outbreaks in the spring have invariably followed winters of abnormally heavy rainfall. The total rainfall recorded at the Waite Institute from April to August, 1932, was 20 inches; the average rainfall recorded at Adelaide for the same months over 78 years is 12.7 inches. Thus, on the assumption that a heavy winter rainfall is favorable to thrips increase, the spring of 1932 can be regarded as one in which a thrips outbreak was possible.

From the data presented in Figs. 1, 2, and 4, it is apparent that the emergence of the first spring generation was spread over a long period; hence the appearance of the second generation was delayed. Also, as shown in all three figures, and in the numbers given in Table I., the increase in the numbers of thrips of the second generation compared with its predecessor was negligible.

Owing to the cold wet weather prevailing during October, the length of the second generation was protracted, the third generation not appearing until November, and it was not until the appearance of the fourth generation, at the beginning of December, that any appreciable increase in thrips was evident. This increase was due more to overlapping waves of emergence, the result of high temperatures, than to actual multiplication as the result of reproduction.

If a chart similar to Fig. 1 had been constructed for the 1931 season, the maximum value of the population curve at the end of October would have been four times that of the maximum value reached in 1932.

5. Notes on Associated Blossom Thrips.

(a) *Thrips tabaci*.—This species, of which only females have been found in South Australia, is present in small numbers throughout the year, but during the twelve months over which records have been kept, it has never become very numerous. A statement made on page 30 of C.S.I.R. Pamphlet 30, to the effect that *T. tabaci* does not begin to reproduce until the end of October, should be modified, as in each of eight sample counts from ageratum, taken between the middle of August and the end of October, not only were individuals of the species found in comparatively high numbers, but there were also nymphs in every sample taken. It is most abundant and widely distributed during the summer months.

(b) *Isoneurothrips australis* has two periods of increase during the year, namely, autumn and spring. The autumn increase carries on longer than in the case of *T. imaginis*, and the spring one begins earlier. During the periods of favorable meteorological conditions, *I. australis* is distributed in a wide range of host plants, but in the summer, with the exception of stray individuals, it is confined to *Eucalyptus* blossom.

(c) *Frankliniella insularis* is only abundant during the summer, and was absent from all records made between May and November. During December, January, February, and March, it is widely distributed over a wide range of plants, of which carnations are the most favoured. Neither this species nor *T. tabaci* confine their feeding to blossom to such an extent as *T. imaginis*; they are frequently found feeding on leaves.

(d) *Haplothrips victoriensis* is abundant from the beginning of December until the end of March, is present in reduced but quite high numbers, from April to June, and persists throughout the winter and spring at a low level of abundance.

(e) *Other Species*.—The species mentioned above have been selected for notice since they occur persistently during certain months in blossom with *T. imaginis*. None of them has such a wide range of hosts as *T. imaginis*, and it may be that none of them has such a short life-cycle. Six other species have occurred in the samples taken, but little information has been gathered concerning their range of host plants or season of abundance.

6. Conclusions.

The data presented in this paper consist of records of field observations. Correlation of meteorological records with population fluctuations will indicate the factors influencing the rise and fall in thrips abundance. Before an accurate analysis of the effect of the different factors involved can be attempted, laboratory experiments will have to be carried out to elucidate many points.

Although the records given here have been made in South Australia, the picture of the seasonal fluctuations in numbers of *Thrips imaginis* they present will be found to be very similar to the conditions obtaining elsewhere in temperate Australia, excepting during the winter. In this season, in the colder parts of Victoria and New South Wales, it is probable that there is a true dormant period, or hibernation, rather than a slow development. The effect of low winter temperatures and rainfall, in this respect, has yet to be investigated.

7. Acknowledgments.

The author is indebted to Dr. J. Davidson for considerable assistance in the work described, and for help in the preparation of this paper. Acknowledgment is also due to Mr. N. Wicks, of Balhannah, and Mr. H. E. Stephenson, of Kersbrook, for their co-operation in the matter of taking samples of apple blossom for recording their thrips population.

Appendix.

METHODS OF CALCULATING THE DURATION OF GENERATIONS
OF *THRIPS IMAGINIS*.

In a previous publication (C.S.I.R. Pamphlet 30, 1932), data were presented in connexion with the development of *Thrips imaginis* at various constant temperatures, and from this data a temperature-development curve was calculated for the complete development of an individual from egg-laying to adult stage.

It has been shown by other workers that the rate of the development of the insect embryo may have a different velocity to that of the succeeding developmental stages. Accordingly, from the available data, separate curves (Fig. 6) have been constructed for two stages.

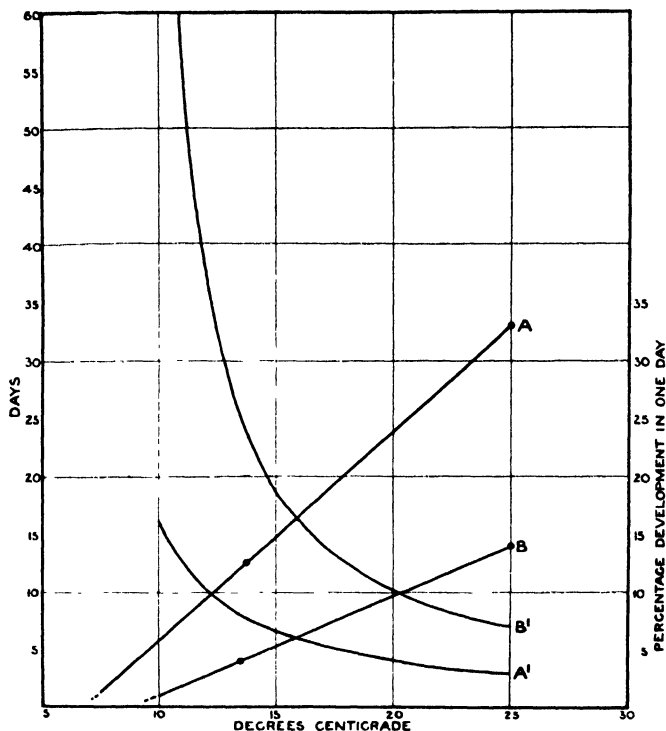


FIG. 6. Temperature-development curves and temperature-velocity curves of *Thrips imaginis* for the periods egg-laying—egg-hatching (A), and egg hatching—egg-laying (B.)

The temperature-development curves have been plotted in accordance with the formula $d = \frac{K}{t - c}$ where d = the developmental period in days; t = temperature in degrees Centigrade; c = the developmental zero, and K = the thermal constant. Using the data from observations at two different constant temperatures, the developmental zero for each stage was calculated from the formula $c = \frac{dt - DT}{d - D}$

For the period, egg-laying (E.L.) to egg-hatching (E.H.), the developmental zero is 6.6° C., and for the period egg-hatching to egg-laying, 9° C. The points plotted on the E.H. to E.L. curve represent not merely the periods to adult stage, but include also the period until the eggs are mature and oviposition can take place.

Thus, at 13.5° C., where the period E.H. to adult is 23 days, two extra days are allowed for the maturation of the eggs. At 25° C., the period E.H. to adult is six days, and one extra day is allowed. The two periods are both based on observations. For the period E.L. to E.H., the thermal constant is 55.2° C., and for the period E.H. to E.L., 112.5° C.

The periods of the generations obtained by this method are approximate only, since they are derived from observations on the development of the insect at constant temperatures, and such conditions do not occur in nature.

Closest correlation between the periods of calculated and observed generations might be expected when the calculations are based on medial temperatures, that is, those temperatures whose range lies on the straight line portion of the velocity curve, since development will not be influenced by retardation resulting from high temperatures, nor by the lag effect consequent on low temperatures.

It would seem that with *T. imaginis* the developmental zero is close to the point where the velocity curve intersects the temperature axis. The periods of generations, calculated by summation of effective mean temperatures, until the thermal constant is reached, are almost identical with corresponding periods arrived at by averaging the mean daily temperatures, and referring the resulting mean temperature obtained to the development curve (Fig. 6).

In Table IV., column 8, the generation periods are calculated by the latter method, those in column 9 by the former. No claims are made that calculations of the periods of generations based on this method are strictly accurate, but they serve to define their approximate duration.

TABLE IV.—CALCULATED LENGTH OF GENERATIONS OF THRIPS IMAGINIS FROM APRIL TO DECEMBER, 1932.

Generations.	Date of commencement of generations (E.L.).	Eggs—hatch (E.H.).	Average mean temperature in ° C. E.L. to E.H.	Average mean temperature in ° C. E.H. to E.L.	Total rainfall in points during each generation	Average number of thrips in one rose.	Length in days of complete generation.	Length in days of corresponding generations, calculated by summation of effective mean temperatures.
1	18th April	26th April	14.7	15.9	96	3, ♂ 6, ♀	26	23
2	14th May	20th May	15.9	14.9	288	6, ♂ 20, ♀	26	28
3	9th June	24th June	10.5	11.0	1,083	1, ♂ 8, ♀	78	78
4	26th Aug.	4th Sept.	12.8	13.3	250	1, ♂ 19, ♀	36	35
5	1st Oct.	10th Oct.	13.1	13.6	259	12, ♂ 75, ♀	32	34
6	3rd Nov.	9th Nov.	18.0	18.0	30	80, ♂ 187, ♀	19	20
7	22nd Nov.	26th Nov.	19.8	22.1	12	138, ♂ 216, ♀	13	15
8	4th Dec.	8th Dec.	19.9	20.6	10	30, ♂ 71, ♀	14	15
9	18th Dec.	22nd Dec.	21.7	17.2	26	8, ♂ 37, ♀	18	16

May 14th has been taken as a suitable starting point from which to calculate the periods of the generations. Reference to Fig. 1 in the main part of the paper, will show that the first appreciable increase in the numbers of thrips was recorded on this date. From this date, the length of the previous generation has been calculated, and the number of generations which developed until the end of the calendar year. From November onwards, high temperatures may exert a harmful effect. Above 25° C., the velocity of development changes and proceeds at a slower rate up to 30° C. Above that point, the effect of high temperatures has not been investigated, but there can be no acceleration, and in all probability the velocity will be considerably retarded. Consequently, the figures given for the lengths of the last four generations are probably smaller than would be the case had it been possible to make accurate corrections for degrees of temperatures recorded over 25° C.

In Table V., the lengths of the generations actually observed during the past spring are given.

TABLE V.—OBSERVED PERIODS OF GENERATIONS OF THRIPS IMAGINIS FROM AUGUST TO NOVEMBER, 1932.

Generations.	Roses.		Salvation Jane.		Cape Weed.	
	Beginning of generations.	Length in days.	Beginning of generations.	Length in days.	Beginning of generations.	Length in days.
1	✓ 26th Aug.	48	27th Aug.	46	26th Aug.	45
2	13th Oct.	25	12th Oct.	23	10th Oct.	25
3	7th Nov.	15	4th Nov.	18	4th Nov.	..
4	22nd Nov.	..	22nd Nov.	..	..	..

¹ Both calculations and observations indicate that the spring emergence or first spring generation commenced on 26th August, and that the fourth spring generation first appeared on 22nd November, but the calculated periods of the first two generations differ considerably from the observed. The influence of rainfall on the environment of the insect is little understood; hence no explanation can yet be offered to account for this divergence. A comparison of Table IV. with Fig. 1 will show that the calculated duration of the first autumn generation coincides with the observed duration. The same correlation is evident with the second autumn generation, which extends through the winter. In the locality where these observations have been made, it is evident that a slow development of the insect in its different stages takes place throughout the winter. It is probable, however, that in parts of Victoria where winter temperatures frequently fall below the developmental zero, conditions approaching true hibernation may obtain.

The Composition of Different Regions of Mounds of *Eutermes exitiosus* Hill.

By F. G. Holdaway, M.Sc., Ph.D.*

Summary.

In the development of standard laboratory colonies of *Eutermes exitiosus* Hill, it has been necessary to decide on the most suitable kind of mound material to be used. Analyses of five mounds have served as a basis for studying the variation in composition of the three regions of the mound. The variation in composition of the inner wall is small, and is only slightly more than that of the nursery. Since the nursery provides only a small amount of material while the inner wall provides a large bulk, the inner wall has been decided on for laboratory colonies.

1. Introduction.

The study here reported forms one phase of the development of standard laboratory colonies for testing timbers for relative resistance to "white ant" (termite) attack, and for studying treatments for preventing attack. The aim of the work is to develop laboratory colonies which are standard as regards population of termites and amount of nest material. These will be maintained in the laboratory under satisfactory controlled physical conditions which are being determined. Preliminary inquiries along these lines have been reported elsewhere by Mr. G. F. Hill (1930), whose initial studies have paved the way for those now in progress.

Eutermes exitiosus is considered by Hill (1932A) to be one of the most important economic species of termite in South-Eastern Australia. In passing, it is of interest to note that this species does not contain the cellulose-digesting Protozoa which Cleveland (1923) formerly considered were essential for the digestion of wood by wood-eating termites. Bacteria are present, and possibly they perform for *Eutermes* the function performed by Protozoa in other species.

The mound of *Eutermes* is composed of three regions with fairly definite limits, (i) the outer wall averaging about 3 inches in thickness and composed of earthy material with large galleries, (ii) the inner wall, tough and woody, 5 or 6 inches in thickness, with a lower proportion of earthy material and a higher proportion of organic matter, and (iii) the "nursery,"† which occupies the centre of the mound and extends below the ground level. (Vide Plate 1.) It is composed of brittle woody material forming the thin walls of an intricate system of galleries. The average dimensions of mounds of the size used in this work are as follows. The average is based on seventeen mounds:—

Horizontal Dimensions (at ground level).	Height.	Outer Wall.	Inner Wall.	Nursery.	
				Vertical Dimensions.	Horizontal Dimensions.
3' 4" x 3' 7"	16"	3·5"	5·5"	13"	x 14"

* An officer of the Division of Economic Entomology.

† The name "nursery" is used for this region of the mound, since, in general the queen is located there and there eggs are laid and juveniles reared. Nevertheless, the nursery is not restricted to these uses. Workers and soldiers, and nymphs and winged forms too, at certain times of the year, particularly in the cold weather, congregate there in large numbers.

PLATE 1.



FIG. 1. Mound of *Eutermes exitiosus*.

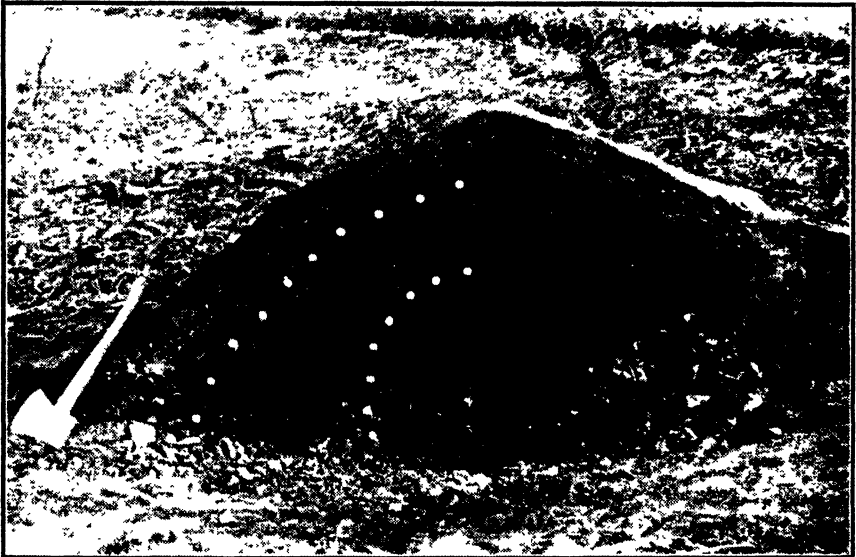


FIG. 2. The same mound cut vertically to show the three regions, outer wall, inner wall, and nursery. The limits of the regions are indicated on the left side of the mound by means of white headed nails. The photo also shows that the nursery extends below ground level.

Details of the procedure developed for setting up laboratory colonies will be given later. For the present, all that it is necessary to mention is that a known amount of termites is placed in a quart jar with definite amounts of wood and nest material of known moisture contents. There is a certain amount of food material available in the mound for the termites, and as the composition of the different regions is different, it has been necessary to determine the most satisfactory kind of mound material to use. Further, as the colonies are to be as standard as is practicable, it is necessary to use mound material which is fairly constant in composition and to know the degree of variation in its composition.

2. Analysis of Mounds of *Eutermes exitiosus*.

Five mounds of the size usually used to provide both mound material and termites for laboratory colonies were selected in a variety of situations in the neighbourhood of Canberra from which mounds are usually collected. Particulars of these mounds are given in Table 1.

TABLE 1.—PARTICULARS OF MOUNDS USED FOR ANALYSIS.

Number of Mound.	Dimensions.		Aspect.	Slope.	Soil.	Remarks.
	Horizontal.	Vertical.				
1	3' 8" x 3' 10"	15"	N.W.	Slight ..	Gravelly	
2	3' 3" x 3' 8"	17"	N.N.W.	Moderate	Grey shale	Mound against stump of tree
3	3' 4" x 3' 8"	22"	E.N.E.	Slight ..	Grey shale tending to yellowish	Butt of tree incorporated in mound
4	3' 4" x 3' 6"	14"	N.N.W.	Moderate	Brown shale	Mound on ridge. Nest of meat ants <i>Iridomyrmex detectus</i> Sm. near edge of mound. Samples obtained from opposite side
5	3' 3" x 3' 8"	19"	N.N.E.	Moderate	Yellowish brown gravel	Fairly open surroundings. Thick, friable, outer wall

Portion of each region of each mound was broken up and freed from termites. Samples of each, 3 lb. in weight, were then forwarded to the Waite Institute, Adelaide, for analysis. (The total nursery material suitable for analysis usually weighed a little less than 3 lb.) The results of the analysis, made by Mr. C. S. Piper, are given in Table 2. The percentage of inorganic material is obtained by subtracting the percentage of organic material from 100.

In Table 3, the variation in composition of the different regions is given in terms of the coefficient of variation $\left(\frac{\text{Standard Deviation}}{\text{Mean}} \times 100 \right)$.

TABLE 2.—ANALYSIS OF MOUNDS OF *Eutermes exitiosus*.

(All results expressed on oven-dry basis.)

Mound No.	Region.	Inorganic Material.	Organic Material (Loss on Ignition).	Nitrogen.	Organic Carbon.
		%	%	%	%
1	Outer wall ..	52.14	47.86	0.349	25.3
	Inner wall ..	20.5	79.50	0.550	43.7
	Nursery ..	14.22	85.78	0.631	47.3
2	Outer wall ..	52.9	47.1	0.31	25.3
	Inner wall ..	14.2	85.8	0.49	47.9
	Nursery ..	11.0	89.0	0.58	49.9
3	Outer wall ..	65.9	34.1	0.27	17.3
	Inner wall ..	15.0	85.0	0.575	47.5
	Nursery ..	6.2	93.8	0.74	52.8
4	Outer wall ..	65.3	34.7	0.27	18.3
	Inner wall ..	8.6	91.4	0.69	50.9
	Nursery ..	11.0	89.0	0.75	51.1
5	Outer wall ..	81.6	19.4	0.135	7.5
	Inner wall ..	16.8	83.2	0.53	46.1
	Nursery ..	12.9	87.1	0.64	48.9

TABLE 3.—COMPARISON OF THE VARIATION IN COMPOSITION OF DIFFERENT REGIONS OF MOUNDS OF *Eutermes exitiosus*.

Region.	Component.	Coefficient of Variation ($\frac{\text{Standard Deviation}}{\text{Mean}} \times 100$).
Outer wall	Organic material	31.8
	Organic carbon	39.1
	N ₂	29.9
Inner wall	Organic material	5.1
	Organic carbon	5.6
	N ₂	13.6
Nursery	Organic material	3.4
	Organic carbon	4.2
	N ₂	11.0

It will be seen that there is least variation in the nursery. The inner wall shows a variability only slightly greater than that of the nursery, while the maximum variation is found in the outer wall. The nursery, with its open structure and thin walls, provides very little bulk. It could thus provide nest material for only a small number of laboratory colonies. The inner wall, on the other hand, provides a much greater bulk. This fact and the fact that the variation in composition is very little greater than that of the nursery have led to the decision to utilize the inner wall for laboratory colonies.

3. The Lignin and Cellulose Content of the Three Regions of a Mound of *Eutermes exitiosus*.

Since lignin apparently has no food value for termites (Cleveland 1925) and is thus apparently excreted unaffected by the digestive juices, the lignin content of the different regions of a mound should give an indication of the proportion of excrement in each region.

The three regions of mound No. 1 have been analysed for lignin, cellulose, and total pentosans by Mr. W. E. Cohen, of the Division of Forest Products. An account of this analysis is given elsewhere (Cohen 1933). The results, Tables 4 and 5, show that the lignin content is highest in the nursery, whilst there is also a high lignin content in the inner wall. The proportion of excrement used in the construction of the nest is thus highest in the nursery and lowest in the outer wall.

TABLE 4.—RESULTS OF ANALYSIS OF MOUND NO. 1 EXPRESSED AS PERCENTAGES OF OVEN-DRY WEIGHT OF ORIGINAL MATERIAL.

Location of Samples.	Total Combustible Matter.	Amount Soluble in 0.5 per cent. NaOH.	Cellulose.	Lignin.	Ratio Lignin : Cellulose.	Total Pentosans.
Outer wall ..	48.3	36.9	2.4	11.5	4.8	4.7
Inner wall ..	79.9	43.6	5.6	23.8	4.3	8.0
Nursery ..	86.0	46.1	7.3	27.0	3.7	7.2

TABLE 5.—RESULTS OF ANALYSIS OF MOUND NO. 1 EXPRESSED AS PERCENTAGES OF OVEN-DRY COMBUSTIBLE MATERIAL.

Location of Samples	Cellulose.	Lignin.	Total Pentosans.
Outer wall	5.0	23.8	9.7
Inner wall	7.0	29.8	10.0
Nursery	8.5	31.4	8.4

The presence of cellulose in a more or less uniform proportion to lignin in all parts of the mound suggests that a proportion of cellulose is undigested by the termites and is passed to the exterior with the lignin. *Eutermes exitiosus* is a wood-feeding termite. The ratio of lignin to cellulose in its food would therefore be about 2 : 1, and this ratio has been changed by digestion of cellulose to 1:4. (A similar change from a lignin:cellulose ratio in camphor wood of about $2\frac{1}{2}$:1 to a ratio of about 1:4 in the nest is recorded by Oshima (1919) for *Coptotermes formosanus*.) A close examination of the lignin:cellulose ratio shows, however, that there is a definite increase in this

ratio from nursery to outer wall. It has been pointed out by Mr. T. Greaves that constructional work on the termitarium is greater in the outer layers than in the inner, and that the termites work from inside. It appears then that the explanation of the higher lignin:cellulose ratio in the outer layers of the mound is that, during constructional work, portions of the mound are eaten and a further proportion of the undigested cellulose is digested and absorbed.

4. Acknowledgments.

I am indebted to Mr. C. S. Piper, of the Waite Institute, Adelaide, for the analyses on which the study of variation in composition has been made, and to Mr. W. E. Cohen, of the Division of Forest Products, Melbourne, for the determination of lignin and cellulose. It is also a pleasure to acknowledge my indebtedness to Mr. G. F. Hill whose wide knowledge of termites in general and of *Eutermes exitiosus* in particular has always been readily made available to me.

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An Analysis of Termite (*Eutermes exitiosus*) Mound Material.

By W. E. Cohen, B.Sc.*

1. Introduction.

In the course of investigations that are being undertaken by the Division of Economic Entomology, and which have as their object the development of a standard laboratory termite colony, consideration is being given to the chemical composition of natural mound material. Preliminary examinations of some samples having indicated that the greater proportion of the material was of organic origin, the determination of cellulose, lignin, and other woody constituents was undertaken at the request of the Division of Economic Entomology.

2. Nature of Investigation.

Since the mound material was not entirely of organic origin, it was necessary to improvise methods of analysis. The application of these methods was not without difficulties, and hence the following brief description of the methods finally employed may be of interest.

Termite mound material consists of (i) organic substances, many of which may be recognized as degradation products of wood or other cellulosic materials, and (ii) inorganic substances apparently including clay, which is possibly the cementing material employed by the termites. The presence of this clay presents difficulties when attempts to determine cellulose, lignin, etc., are made. Such determinations involve a number of chemical operations, each of which introduces a filtering process at some stage or other. With such a substance as clay present, and with no possible means of altering its colloidal condition without affecting the organic constituents of the mound material, none of the usual filtering processes can be employed. Thus, such filtering media as alundum crucibles, fritted glass, Gooch crucibles, and filter paper soon become impervious. Furthermore, the latter cannot be used with safety when the determination involves its own substance, i.e., cellulose. The only alternative to filtering during this analysis was to centrifuge, and, therefore, throughout the methods that are described below, all operations involving the separation of solids from liquids were carried out by centrifuging.†

3. Methods of Analysis.

Cellulose was determined by means of a procedure which differed in detail only from that described by J. A. Daji for the determination of cellulose in soil(1), and any reservations which apply to the results obtained by using his method must necessarily apply to those recorded in this paper. The procedure employed was as follows:—

Duplicate samples were weighed out in each case, approximately 3 gms. of material being taken for each duplicate, and a moisture determination (by oven-drying at 105° C.) was made for each sample at the time of weighing out. The accurately weighed samples were

* An officer of the Division of Forest Products.

† NOTE.—It is of interest to mention that numerous delays, caused by the shattering of the glass centrifuge tubes at the high speed of the machine in use, were finally avoided by the introduction of a water cushion between the glass tubes and the metal centrifuge cups.

placed in beakers (250 cc.) and 0.5 per cent. sodium hydroxide solution (80 cc.) was added to each sample. The covered beaker and its contents were heated in a boiling water-bath for 30 minutes, after which they were allowed to cool and the solid material to settle. The supernatant liquor was decanted and centrifuged for 15 minutes before being discarded. All residual solid material was transferred to the beaker using 1 per cent. hydrochloric acid (80 cc.), after which the contents of the beaker were heated in a boiling water bath for 30 minutes and then allowed to cool and settle. The supernatant liquor was decanted with a siphon tube and centrifuged for 10 minutes. The residue in the beaker was washed four times with hot water (80 cc. each time). On each occasion, the contents of the beaker were separated by decantation and centrifuging. By this time, the solid residue was acid-free, and, after removing all excess water by centrifuging, the material was returned to the beaker using cold water (76 cc.) and 4 cc. of sodium hypochlorite (containing 15 per cent. available chlorine) was added. The mixture was allowed to stand in the cold, with occasional stirring, for 30 minutes. It was then centrifuged for 15 minutes and the supernatant liquor was discarded. This delignification process was repeated until the supernatant liquor was only the colour of sodium hypochlorite of the same strength. For outer and inner wall material, two, or at the most three, treatments sufficed. For the nursery material, five such treatments were necessary, indicating a greater lignin content. Each treatment was followed by centrifuging and the discarding of the supernatant liquor. Between each treatment one wash with cold water (40 cc.) was given to the material contained in the centrifuge tubes.

At this stage, Daji recommended the addition of dilute hydrogen peroxide, in small amounts at a time, until effervescence ceased, excess being avoided. In the present investigation, centrifuging and washing made it possible to remove all hypochlorite. At any rate, when hydrogen peroxide (20 cc. of 10 vol. H_2O_2 diluted to 100 cc.) was added in small amounts to the residue, no effervescence occurred. It was therefore considered that this part of the procedure could be safely omitted and some time saved.

The delignified residue was next given a cold water wash (80 cc.), and the wash liquor removed by centrifuging. Hot water washes (80 cc.) were then employed, the residue, on each occasion, being transferred to the beaker for the purpose. Finally, the wash liquors were found to be neutral, and, therefore, evaporation to dryness over a water bath could then be undertaken without harmful effects. For this purpose, the residue was transferred to an evaporating basin with the aid of water from a wash-bottle. The dried material was broken up as much as possible and carefully transferred to a measuring flask (100 cc.) using exactly 100 cc. of Schweizer's solution* during the process. The stoppered flask and its contents were then shaken in a rotary shaker for eight hours at the rate of 50 shakes a minute. The remaining solid material was then allowed to settle overnight. By means of a siphon tube, more than 50 cc. of the clear supernatant liquor was decanted into a stoppered Erlenmeyer flask. From the latter, using a pipette, exactly 50 cc. of the solution was added to 200 cc. of alcohol (80 per cent. by weight) contained in a beaker

* Of a number of methods that were tried, the most satisfactory procedure for the preparation of Schweizer's solution was that which has been described by many investigators and which involves the passing of air through strong ammonia in which copper turnings are suspended.

(400 cc.), and the precipitate thus formed was allowed to settle overnight. The supernatant liquid was then decanted through a weighed alundum crucible (R.A. 98) or a weighed Gooch crucible fitted with an acid-treated and previously ignited asbestos pad, the latter being the more suitable. After the upper liquid had all been filtered, 50 cc. of a mixture of alcohol and hydrochloric acid (40 cc. of 80 per cent. alcohol plus 10 cc. HCl.) were added to the precipitate in the beaker; the mixture was stirred till all the copper hydroxide was dissolved, and was then allowed to stand for about one hour. The upper liquid was then filtered through the same crucible, the precipitate washed free of copper with hot water, then transferred to the crucible, washed further with hot water, and then with alcohol and ether in turn. The crucible and its contents were dried in an oven at 105° C. for two hours, and then weighed, ignited for 30 minutes in a muffle furnace at 600° C., and again weighed. The loss in weight on ignition multiplied by two represented the amount of cellulose in the original sample of mound material.

Lignin was determined in mound material which had previously been extracted with 0.5 per cent. sodium hydroxide at the temperature of the boiling water bath for one hour and washed free from alkali. The purified residue was treated in the cold with 72 per cent. sulphuric acid(2), and subsequently with boiling 3 per cent. sulphuric acid in order to hydrolyse all carbohydrate material. The solid residue consisted of lignin and inorganic substances. After it had been washed free of acid, it was evaporated to dryness in a platinum dish, dried in the oven at 105° C., and weighed. The amount of lignin present was determined by igniting the oven-dried residue, and re-weighing, the loss in weight being estimated as lignin.

Total pentosans were determined by the procedure usually employed in wood analysis(3). It was found that 2 grams of the outer wall material and 1 gram of each of the inner wall and nursery materials were required in order to conform with the conditions of the method.

Solubility in 0.5 per cent. sodium hydroxide was determined by extraction of about 3 gms. of material with 100 cc. of the alkali solution for one hour at the temperature of a boiling water bath. After centrifuging, washing, neutralizing with dilute acetic acid solution, and further washing, the residual material was dried and weighed.

4. Results of Analysis.

The results of an analysis of the material from the outer wall, inner wall, and nursery of one termite (*Eutermes exitiosus*) mound are as follows (Table 1):—

TABLE 1.—RESULTS OF AN ANALYSIS OF OUTER WALL, INNER WALL, AND NURSERY MATERIALS FROM ONE MOUND, EXPRESSED AS PERCENTAGES OF THE OVEN-DRY WEIGHT OF ORIGINAL MATERIAL.

Location of Sample.	Total Combustible Matter.	Amount soluble in 0.5% NaOH.	Cellulose.	Lignin.	Ratio Lignin to Cellulose.	Total Pentosans.
Outer wall ..	48.3	36.9	2.4	11.5	4.8	4.7
Inner wall ..	79.9	43.6	5.6	23.8	4.3	8.0
Nursery ..	86.0	46.1	7.3	27.0	3.7	7.2

On account of the greater proportion of non-combustible material contained in the outer wall material, the results in Table 1 do not clearly reveal the fate of the ligno-cellulose substances which had originally been attacked by the termites. The following results (Table 2) have, therefore, been expressed on the basis of combustible material:—

TABLE 2.—SHOWING RESULTS OF ANALYSIS OF OUTER WALL, INNER WALL AND NURSERY MATERIALS FROM ONE MOUND, EXPRESSED AS PERCENTAGES OF OVEN-DRY COMBUSTIBLE MATERIAL.

Location of Samples.				Cellulose.	Lignin	Total Pentosans.
Outer wall	..	..	..	5	24	10
Inner wall	..	..	..	7	30	10
Nursery ..	..	..	..	9	31	8

The results included in Table 2 might conveniently be contrasted with the values for hardwoods (eucalypt) and a softwood (spruce) which are indicated in Table 3—

TABLE 3.—RESULTS OF ANALYSIS OF HARDWOODS (EUCALYPTS) AND A SOFTWOOD (SPRUCE) EXPRESSED AS PERCENTAGES OF OVEN-DRY MATERIAL.

Type of Wood.				Cellulose.	Lignin.	Total Pentosans.
Hardwoods (eucalypts)	..	..	..	34 to 59	18 to 25	9 to 23
Softwood (spruce)	..	..	..	62	25	10

5. Conclusions.

It is apparent from the above figures (Tables 2 and 3) that the cellulose in the wood attacked by the termites is very considerably degraded as shown by the high percentage of material soluble in weak sodium hydroxide solution and the low percentage of cellulose in the organic matter. On the other hand, the percentage of lignin is of the same order of magnitude expected in wood substance, and therefore appears to have been little altered.

The extent of the change in the cellulose might indicate that the wood substance of the mound material has passed through the digestive tracts of the termites during which process only the cellulose constituents have been altered.

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The Inheritance of Fluorescence in Hybrids between Perennial Rye-Grass and Wimmera Rye-grass.

By H. C. Trumble, M.Agr.Sc.,* and I. F. Phipps, M.Sc., Ph.D.†

The article that follows has been furnished by the Director of the Waite Agricultural Research Institute (Professor A. E. V. Richardson), with an indication that it should be regarded as an integral part of the programme of investigational work on the mineral deficiencies of pastures in which the Institute, the Empire Marketing Board, and the Council are co-operating. An account of this work was given in a previous issue of this *Journal* (Vol. 5, No. 3, August, 1932, p. 141), and also in the Council's Pamphlet No. 17.—ED.

Summary.

1. Wimmera rye-grass, when self-fertilized, produced both non-fluorescent and fluorescent seedlings, all of which, when grown to maturity, proved to be annual plants with variable but typical Wimmera rye-grass characteristics. Annual plants of Wimmera rye-grass, homozygous for non-fluorescence, have been isolated.

2. Hawke's Bay perennial rye-grass (*Lolium perenne*), when self-fertilized, produced non-fluorescent seedlings, all of which proved to be truly perennial.

3. The F₁ hybrids between Wimmera and Hawke's Bay rye-grass were perennial, but principally of the "short-lived perennial" type, and were either fluorescent or non-fluorescent, depending on whether a fluorescent or a non-fluorescent gamete from Wimmera rye-grass was effective in fertilization.

4. Fluorescence is inherited as a dominant character, dependent on one, and possibly two, genetic factors giving 3:1 and 9:7 ratios respectively.

5. The heterozygosity of Wimmera rye-grass for fluorescence and the non-fluorescent character of the annual rigid rye-grass (*L. rigidum*) indicate that the occurrence of fluorescence with annual or short-lived habit in Italian rye-grass (*L. multiflorum*), Wimmera rye-grass, and "false-perennial" rye-grass is merely a chance association.

6. Thus, in certain cases, when Wimmera rye-grass is growing in proximity to, or in association with, perennial rye-grass, the ultra-violet light test for perenniality may give a false estimate of the percentage of true perennial plants in the seed collected.

7. It is argued that the heterozygosity of Wimmera rye-grass for fluorescence lends support to the view that Wimmera rye-grass has originated from hybridism between Italian rye-grass (*L. multiflorum*) and rigid rye-grass (*L. rigidum*).

8. As Wimmera rye-grass is a segregating hybrid, it should not receive specific rank, and there is no justification for the botanical equivalents (*L. subulatum*, *L. rigidum* var. *strictum*, and *L. hybridum*) which have been applied.

1. Introduction.

Considerable interest has recently been aroused by the discovery of Gentner (4) that the roots of Italian rye-grass seedlings, when grown in contact with white filter-paper, produce a substance which exhibits fluorescence when exposed to filtered ultra-violet light. Linehan and Mercer (7), working with commercial rye-grasses, showed that Italian rye-grass (*Lolium multiflorum* Lam.) and the hybrid or "false perennial" types occurring in commercial samples exhibited the fluorescent

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† Geneticist, Waite Agricultural Research Institute.

character, whereas true perennial rye-grass (*Lolium perenne* L.) was non-fluorescent. The practical importance of this differentiation lies in the means it affords of separating the seeds of perennial rye-grass from those of Italian rye-grass and inferior hybrid derivatives.

Foy (3), discussing the application of these results to New Zealand rye-grasses, states that all annual species of rye-grass exhibit complete fluorescence. This generalization is apparently based on the evidence of Linehan and Mercer (*loc. cit.*), who recorded it in Italian rye-grass, Western Wolths (*L. multiflorum* Lam. var. *Westernwoldicum*), darnel (*L. temulentum* L.), *L. remotum* Schrank., and *L. Brazilianum* Nees., and on Foy's own experience with Wimmera rye-grass.

In view of the increasing importance of both perennial rye-grass and the annual Wimmera rye-grass, in South Australia, the authors carried out hybridization experiments with selected plants of these two types during 1931. The object of this work was (i) to test the suggestion that annual and perennial habit were associated with fluorescence and non-fluorescence respectively, and (ii) to study the inheritance of the fluorescent character.

In the meanwhile, Corkhill (1) published a note on the inheritance of fluorescence in natural hybrids between *L. multiflorum* and *L. perenne* showing that these apparent hybrids, when self-fertilized, segregated in ratios approximating 3 fluorescent to 1 non-fluorescent. Still later, Linehan and Mercer (8), although they did not present data, published a note to the effect that fluorescence was inherited as a simple Mendelian dominant, and was not necessarily associated with the annual habit.

2. Material and Methods.

The parents employed consisted of typical Wimmera rye-grass plants selected from a commercial line, and perennial rye-grass plants selected from a certified Hawke's Bay (New Zealand) sample. The parent plants were collected from the experimental field and transplanted to pots, which were spaced at intervals within a large glass house.

Direct and reciprocal crosses were made by means of the emasculation and hand pollination method. In addition, several inflorescences of each parent were protected from cross-fertilization by bagging. Self-fertilized and reciprocally crossed seeds were not obtained in all cases, owing to pollen sterility and self-incompatibility in some parents.

The seeds obtained from the hybridization and self-fertilization of the parents were germinated on filter paper, and the filter papers subjected to the standard ultra-violet light test. The seedlings producing fluorescence were separated from the remainder in each set, and both fluorescent and non-fluorescent seedlings were transplanted to pots, and later planted out as single plants in the experimental field. As many F₁ hybrid plants as possible were self-fertilized, together with plants from each selfed parental line. The seeds obtained from these baggings were then subjected to the ultra-violet light test.

3. The Results of Selling Wimmera Rye-grass and Hawke's Bay Rye-grass.

The parents employed were four Wimmera rye-grass plants (W.1, W.6, W.7, W.8), and six plants of perennial rye-grass (H.B.2, H.B.3, H.B.4, H.B.5, H.B.9, H.B.10). Each of these plants was self-fertilized by bagging, with the results shown in Table I.

TABLE I.—PERCENTAGE FERTILE SEED OBTAINED FROM (a) WIMMERA RYE-GRASS; (b) HAWKE'S BAY RYE-GRASS, WHEN SELF-FERTILIZED.

Parent.			Percentage Fertile Seed.	Parent.			Percentage Fertile Seed.
W.1	..	..	4	H.B.2			†
W.6	..	..	Nil	H.B.3			13
W.7	..	..	46	H.B.4			Nil
W.8	..	..	Nil	H.B.5			3
				H.B.9			Nil
				H.B.10			Nil

† Seed formed, but percentage not recorded.

In both forms of rye-grass, the percentage of seed set as a result of self-fertilization was low. Sterility occurred in both H.B.9 and H.B.10, all the pollen of H.B.9, and 50 per cent. of the pollen of H.B.10 being abortive. On the other hand, W.6, W.8, and H.B.4 developed normal pollen, and produced fertile seeds when hybridized with other plants, indicating that in these three cases self-incompatibility was the reason for the apparent sterility.

Ten seedlings resulting from the self-fertilization of W.1 proved to be true annual* plants, with typical Wimmera rye-grass features, but 7 of these were fluorescent and 3 non-fluorescent at the seedling stage. The parent plant, therefore, was heterozygous for fluorescence, although homozygous for the annual character. Similarly, in the case of W.7, 8 fluorescent and 7 non-fluorescent seedlings were obtained, all of which proved to be typical annuals. In order to confirm the presence of the non-fluorescent character in the annual types, three of the annual plants were selected at random and self-fertilized in 1932. The seeds produced were tested for fluorescence, with the results given in Table II.

TABLE II.—ULTRA-VIOLET LIGHT TEST OF SEEDLINGS RESULTING FROM SELF-FERTILIZED NON-FLUORESCENT ANNUAL PLANTS OF WIMMERA RYE-GRASS.

Pedigree No.		Parent.	Number of Seedlings.			Percentage Germination.
			Fluorescent.	Non-fluorescent.	Total.	
32-136-2	..	W.1	2	8	10	46
32-136-3	..	W.1	1	8	9	41
32-140-1	..	W.7	Nil	62	62	72
Total ..			3	78	81	..

* Plants which did not survive the first summer after planting have in all cases been designated "annuals," whereas all plants which were alive at the commencement of the second growing season have been termed "perennials."

Of the 81 seedlings examined, 78 were non-fluorescent and 3 fluorescent, thus confirming the designation of these three plants as non-fluorescent annuals. The three fluorescent seedlings probably resulted from accidental cross-pollination.

Twenty-one seedlings resulting from the self-fertilization of Hawke's Bay rye-grass parent plants were all non-fluorescent, and proved to be all perennials. Six of these plants were selfed during 1932, but only two produced fertile seeds. The seeds were tested for fluorescence, with the results shown in Table III.

TABLE III.—ULTRA-VIOLET LIGHT TEST OF SEEDLINGS RESULTING FROM SELF-FERTILIZED NON-FLUORESCENT PERENNIAL PLANTS OF HAWKE'S BAY RYE-GRASS.

Pedigree No.	Parent.	Number of Seedlings.			Percentage Germination.
		Fluorescent.	Non-fluorescent.	Total.	
32-133-1 ..	H.B.2	2	149	151	95
32-133-2 ..	H.B.2	2	148	150	86
	Total ..	4	297	301	..

Of the 301 seedlings tested, 4 were fluorescent and 297 non-fluorescent. The 4 fluorescent seedlings obtained are assumed to have resulted from accidental cross-pollination.

4. The Hawke's Bay x Wimmera Rye-grass Hybrids.

(i) *First Generation Plants.*

The classification of F₁ plants into (a) fluorescent and non-fluorescent types, and (b) annuals and "perennials," is shown in Table IV.

TABLE IV.—CLASSIFICATION OF F₁ PLANTS ACCORDING TO (a) SEEDLING ROOT CHARACTER; (b) LONGEVITY.

Hybrid.	Seedlings, Annual.	Fluorescent "Perennial."	Seedlings, Annual.	Non-fluorescent "Perennial."
H.B.2 x W.1 ..	..	..	..	1
H.B.5 x W.8 ..	3	2	..	..
W.8 x H.B.5 ..	..	3	..	..
W.1 x H.B.2 ..	..	8	..	7
W.7 x H.B.4 ..	..	1	..	..
W.6 x H.B.3 ..	..	4	..	..
Total ..	3	18	..	8

The 18 fluorescent "perennial" hybrids obtained were all true crosses, and indicate that the fluorescent seedling character is dominant, and the perennial character at least partially dominant. The incomplete dominance of the perennial character is indicated by the fact that the "perennial" hybrids, at the commencement of the second growing season, possessed fewer and less vigorous green shoots than the inbred Hawke's Bay rye-grass plants. These types in fact tend to resemble the "false perennial" types of Levy and Davies (6).

On the other hand, the 8 non-fluorescent "perennial" hybrids probably result from the union of a non-fluorescent annual gamete from Wimmera, with a non-fluorescent perennial gamete from Hawke's Bay rye-grass. This is obviously true in the W.1 x H.B.2 cross, in which W.1 was the female parent, and it was previously noted that both W.1 and W.7 were heterozygous for fluorescence (*vide* text p. 172).

The three fluorescent annuals from the cross H.B.5 x W.8 were noted as weak plants lacking in vigour, and may have died owing to poor vitality rather than as a result of an inherently annual character.

(ii) *Second Generation Plants.*

An attempt was made to obtain self-fertilized seeds from all the hybrid plants. Eight plants, however, failed to set seed, four plants produced less than 10 seeds each, and the germination of the seed produced in a number of cases was unsatisfactory. In determining the ratio of segregation into fluorescent and non-fluorescent seedlings, data have been utilized only from plants which produced more than 10 seedlings.

The F₂ segregation of fluorescence and non-fluorescence falls into two groups, one in which the ratio is 3:1, and the other 9:7. The details of the F₂ seedling counts from fluorescent "perennial" F₁ hybrids, the segregation of which approximated to a 3:1 ratio, are shown in Table V.

TABLE V.—THE CLASSIFICATION OF FLUORESCENT AND NON-FLUORESCENT SEEDLINGS FROM F₁ WIMMERA x HAWKE'S BAY RYE-GRASS HYBRIDS, SEGREGATING IN THE F₂ GENERATION ON THE BASIS OF A RATIO APPROXIMATING 3 : 1.

Pedigree.	Parents.	Characters of F ₁ Plant.*	F ₂ Seedling Counts.			D. P.E.	Percentage Germination.
			Fluorescent	Non-fluorescent.	Total.		
32-134-6	W.1 x H.B.2	F.P.	24	10	34	<1	90
32-134-8	"	F.P.	8	3	11	<1	65
32-135-5	"	F.P.	14	4	18	<1	86
32-135-6	"	F.P.	9	4	13	<1	87
32-135-7	"	F.P.	7	4	11	1.3	69
32-135-8	"	F.P.	40	13	53	<1	70
32-142-5	W.7 x H.B.4	F.P.	529	182	711	<1	99
32-149-7	W.8 x H.B.5	F.P.	233	63	296	2.2	81
Total observed			864	283	1,147	..	..
Calculated 3 : 1			860.25	286.75	1,147	1.2	..

* F = fluorescent. P = "perennial."

The above data indicate that in plants arising from the hybrids W.1 x H.B.2, W.7 x H.B.4, and W.8 x H.B.5, there is a segregation of fluorescent and non-fluorescent seedlings in a ratio approximating 3 : 1.

In the F₂ progeny of two F₁ plants of the hybrid W.6 x H.B.3, there is an indication that the segregation is in the ratio of 9 fluorescent; 7 non-fluorescent, as shown in Table VI.

TABLE VI.—THE CLASSIFICATION OF FLUORESCENT AND NON-FLUORESCENT SEEDLINGS FROM F₁ WIMMERA x HAWKE'S BAY RYE-GRASS HYBRIDS, SEGREGATING IN THE F₂ GENERATION ON THE BASIS OF A RATIO APPROXIMATING 9 : 7.

Pedigree.	Parents.	Characters of F Plant.	F ₂ Seedling Counts.			D. P.E.	Percentage Germination.
			Fluorescent.	Non-fluorescent.	Total.		
32-143-5	W.6 x H.B.3	F.P.	51	33	84	1.2	67
32-143-7	"	F.P.	62	42	104	1.0	73
	Total observed	..	113	75	188	..	..
	Calculated 9 : 7	..	105.75	82.25	188	1.6	..

The data shown in Table VI. give an excellent fit to a 9 : 7 ratio, suggesting that two factors are concerned in the production of fluorescence. Although F₃ data is necessary to confirm this ratio, the fact that two plants from the same hybrid segregate similarly is fairly definite evidence.

The 8 non-fluorescent "perennial" plants present in the F₁ group (*vide* Table IV.) were bagged, and 6 of these produced selfed seed. The details of the F₂ seedling counts are given in Table VII.

TABLE VII.—THE CLASSIFICATION OF FLUORESCENT AND NON-FLUORESCENT F₂ SEEDLINGS FROM NON-FLUORESCENT PERENNIAL PLANTS IN THE F₁ GROUP.

Pedigree.	Parents.	Characters of F ₁ Plant.*	F ₂ Seedling Counts.			Percentage Germination.
			Fluorescent.	Non-fluorescent.	Total.	
32-134-2 ..	W.1 x H.B.2	FP	2	52	54	83
32-134-3 ..	"	FP	0	18	18	82
32-134-4 ..	"	FP	3	11	14	42
32-135-2 ..	"	FP	0	62	62	83
32-135-3 ..	"	FP	5	69	74	87
32-135-4 ..	"	FP	3	79	82	85
	Total ..	..	13	291	304	..

* F = non-fluorescent. P = "perennial."

Two plants, 134-3 and 135-2, produced seedlings that were all non-fluorescent; in the remainder, a few fluorescent seedlings appeared in each case. It is assumed that the occurrence of the fluorescent seedlings was due to chance pollination by foreign pollen.

The absence of segregation from the non-fluorescent perennials in the F₁ group confirms the classification shown in Table IV., and lends support to the explanation given, namely, that these have probably resulted from the union of a non-fluorescent annual gamete from heterozygous Wimmera rye-grass, with a non-fluorescent perennial gamete from Hawke's Bay rye-grass.

5. Views Concerning the Origin of Wimmera Rye-grass.

Wimmera rye-grass, as it is known in Southern Australia, is of comparatively recent origin. It was first recorded by Mullett (9) in 1919, but had apparently been known in the Wimmera district of Victoria for 32 years previously. As far as can be ascertained (9,10), the original material was imported from Europe by a Mr. McNichol, of Noradjuha, and the grass was known as Italian rye-grass for many years.

By 1919, this grass had demonstrated an undoubted agricultural value under the comparatively low rainfall conditions of the Wimmera wheat-growing areas. It was identified by Ewart as *Lolium subulatum*, Vis., and Hitchcock, in the United States, confirmed this designation. The name, however, was not accepted in New South Wales (10), where it has been classed as *Lolium rigidum* var. *strictum*, Jansen.

Recently, Morris in Ewart's *Flora of Victoria* (2), designates the grass as *Lolium hybridum* Hausskn (*L. perenne* x *L. multiflorum*) on the evidence that "apparently pure seed grown at Burnley, Rutherglen, Minyip, and in New South Wales yielded *L. perenne* and . . . *L. multiflorum* . . . mixed with the Wimmera rye-grass type." Ewart adds a footnote, however, stating that "if the plant is a segregating hybrid the name *L. hybridum* is not justified." He also suggests that *Lolium rigidum* Gaud. may be native to Victoria, and that it may cross with *L. perenne*, yielding the forms mentioned above.

Seed samples of Wimmera rye-grass which have been tested at the Waite Institute from time to time have invariably yielded a mixture of diverse types, the majority of which range between typical *L. rigidum* and typical *L. multiflorum*, together with a small percentage of short-lived perennial forms. Jenkin (5), reporting on samples grown at Aberystwyth including the progeny of herbarium specimens, also found considerable variation, and concluded that the name "Wimmera" covers a mixture of types, and includes any rapid growing short lived rye-grass.

The majority of the types are strictly annual in character, stemmy in comparison with *L. multiflorum* or *L. perenne*, but leafier and more robust than *L. rigidum*, with a characteristic purplish colouration of the stem at maturity. The "seeds" are usually larger than those of any of the above three species, and may be either awned or awnless. The outer glume of each spikelet is usually well developed, and closely adnate to the rachis at maturity. The rachis is generally stouter than that of *L. multiflorum* or of *L. perenne*, and rather longer and relatively more slender than that of *L. rigidum*. In addition, there are frequently

present plants which closely resemble Italian rye-grass, others that are typically *L. rigidum*, and also occasional plants which are definitely perennial, and possess the botanical characteristics of perennial rye-grass.

Experience with *Wimmera* rye-grass over a period of eight years at the Waite Institute indicates that combinations of the characters present in *L. rigidum* and *L. multiflorum* are of frequent occurrence among the multiplicity of types evident. The more important agronomic and botanical characters such as inherent vigour, relative leaf and stem development, type of leaf shoot and texture of the leaves, rachis and spikelet features, and awn development are extremely variable, but for the most part tend to be intermediate between the above two species.

Moreover, the authors find that *L. rigidum* produces non-fluorescent seedlings as in the case of *L. perenne*, and this negatives Foy's statement that all annual species of rye-grass exhibit complete fluorescence. On the other hand, *L. multiflorum* is completely fluorescent. *Wimmera* rye-grass when self-fertilized yielded both non-fluorescent and fluorescent seedlings, all of which proved to be annuals (p. 172).

The extreme variability of *Wimmera* rye-grass in practically all agronomic and botanical features of importance, to which the occurrence of non-fluorescent and fluorescent types must now be added, indicates that *Wimmera* rye-grass is of comparatively recent origin, resulting from hybridism between the awned, leafy, fluorescent *L. multiflorum*, and the awnless, stemmy, non-fluorescent *L. rigidum*, followed by ecotypical selection. It is very probable that further hybridization between these derivatives and *L. perenne* has also occurred in certain cases. That samples of *Wimmera* rye-grass usually contain a high percentage of fluorescent seedlings is accounted for by the fact that fluorescence behaves as a dominant character, and that the grass is normally cross-fertilized.

Whether the heterozygosity for fluorescence in *Wimmera* rye-grass is widespread, or is merely a local characteristic, is not yet known. In general, intercrossing between *Wimmera* rye-grass heterozygous for fluorescence, and perennial rye-grass will tend to produce approximately 50 per cent. non-fluorescent hybrid seed.

In view of the evidence of segregation for major taxonomic characters in *Wimmera* rye-grass, it is obvious that no specific botanical name can justifiably be applied to this mixture of types.

6. Application of the Results to the Diagnosis of Rye-grass Types.

Recently, there has been a tendency to place much reliance on the ultra-violet light test as a positive means of differentiating true perennial rye-grass from Italian rye-grass and inferior hybrid derivatives.

Since the annual *L. rigidum* is non-fluorescent, however, and as *Wimmera* rye-grass when self-fertilized segregates fluorescent and non-fluorescent seedlings, all of which are annuals, it is evident that fluorescence and non-fluorescence are not necessarily associated with annual and perennial habit respectively. The occurrence of fluorescence in Italian rye-grass, *Wimmera* rye-grass, and "false perennial" types, as contrasted with the non-fluorescence of the annual *L. rigidum* and perennial rye-grass, is thus probably a chance association.

These facts, together with the now widespread distribution of *Wimera* rye-grass, suggest that the ultra-violet light test may give a false estimate of the factors perenniality, type, productivity, &c., on which the value of rye-grass for permanent pasture depends. It is evident, therefore, that the test must be used with discrimination and caution, and that it cannot effectively replace the systems of inspection, sampling, and growing-on as single plants necessary in an efficient scheme of seed certification.

A final point of some interest is the almost invariable occurrence of a trace—usually 1 or 2 per cent.—of fluorescence in even the best and truest perennial rye-grass types. This is demonstrated by Foy's data (3), and has been shown by practically all samples examined at the Waite Institute. In three groups of selfed non-fluorescent plants (Tables II., III., and VII.), the authors unexpectedly obtained a similarly small percentage of fluorescent seedlings among the progeny. The occurrence of these fluorescent types has been tentatively attributed to chance cross pollination with fluorescent forms.

7. Presence of Fluorescence in Subterranean Clover.

During the course of the work, various pasture species have been subjected, whilst germinating on filter paper, to the ultra-violet light test. It has been found that whereas South Australian commercial subterranean clover is non-fluorescent, an early-flowering type from Dwalganup (Western Australia) which is becoming increasingly important in the lower rainfall areas is fluorescent. The fluorescence is, however, faint, and unlike rye-grass, the causal substance is confined to the root tissue, and not exuded.

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An Examination of the Amount of Iodine in the Thyroid Glands of Australian Merino Sheep.

By Mary C. Dawbarn, M.Sc.,* and F. C. Farr.†

The thyroid gland manufactures an iodine-containing compound which is necessary for the normal growth and well-being of men and animals, and for the healthy growth of hair or wool. For this purpose, an adequate supply of iodine in the food is required. An insufficient intake of iodine resulting from deficient iodine in the soil leads to ill-health in both man and animals.

In certain districts of the United States of America, Canada, Switzerland, and New Zealand, goitre, an enlargement of the thyroid gland in the neck, has been very common among human beings and domestic animals from this cause. The effect on sheep has been serious, lambs being born with enlarged thyroids and hairless, and so weak that large numbers of them die.

When the Division of Animal Nutrition was founded in 1927, the late Professor Brailsford Robertson undertook a survey of the iodine available in Australian sheep pastures.‡ The direct determination of the amount of iodine in the soil or the pasture is troublesome and inaccurate, owing to the minute quantity present, but an animal feeding on a pasture accumulates the iodine for its own purposes, and the amount stored in its thyroid glands is a useful measure of the amount available. Consequently, the most satisfactory procedure to test whether the soil contains enough iodine is an analysis of the thyroid glands of the sheep themselves. If this iodine storehouse contains a sufficiency of iodine, there must be a sufficiency of iodine in the pasture. The work of American investigators, notably Marine, has shown that to ensure health the thyroid should contain at least 0.1 gm. of iodine per 100 gm. of dry gland, and that when iodine was abundant in the soil the amount might rise to 1 gm. or even more per 100 gm.

The results of our iodine survey have recently been published in the *Australian Journal of Experimental Biology and Medical Science*, 10, p. 189, 1932, and some of the findings will be given here. Altogether, some 700 thyroid glands from sheep have been examined, and the dry weight and iodine content of each determined. Between 500 and 600 of the glands were obtained from "Meteor Downs," Spring-sure, Central Queensland; "Keytah," Moree, New South Wales; "Buln Gherin," Beaufort, Victoria; "Kolendo," Port Augusta, South Australia; and the south-eastern district of South Australia. The remaining glands were obtained from districts scattered about the Commonwealth, including Tasmania, but not Western Australia.

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‡ For the reason that at this period, many pastoralists have been so influenced by the dramatic results obtained by iodine feeding in other countries that they considered that if full benefit were to be obtained from their pastures, the stock grazing thereon should have access to an iodine-containing lick.

It has been found that there is considerable variation in the weight and percentage content of iodine of glands obtained from animals of the same sex, age, and locality, even when collected at the same time of year. To determine the influence of different factors on the thyroid, it has, therefore, been necessary to calculate the arithmetic mean of the results obtained from considerable numbers of glands in each of the groups to be compared. In this way, it has been possible to show that the sex and age of the sheep have very little, if any, influence on its thyroid iodine. The iodine content is affected more by the season of the year than by the locality from which the glands were collected. Drought has a marked influence on the iodine content. Five glands from "Mutooroo," South Australia, collected during drought, had iodine contents varying from 0.67 to 0.95 per cent.; the iodine content of six glands from "Mutooroo," collected in the good season following the drought, varied from 0.18 to 0.56 per cent. Similarly, the average content of iodine in the thyroids obtained from 38 wethers at "Kolendo," South Australia, during drought, was 0.719 per cent. The figure for twenty wethers obtained in the ensuing good season was 0.441 per cent.

Of all the glands examined, none showed a lower percentage of iodine on dry weight than 0.10, and the highest value obtained was 1.26. The average for all glands was approximately 0.5 per cent. No very enlarged glands were found. Thus there is no evidence of iodine deficiency in Australian sheep pastures as far as this survey extends.

At "Keytah," in northern New South Wales, an experiment has been carried out by the Division of Animal Nutrition to determine the effect of feeding sheep on licks containing potassium iodide. This experiment is described in another communication by E. W. L. Lines (see p. 181 *et seq.*). The amount of potassium iodide in the lick was changed periodically from 1 part in 1,000 to 1 part in 7,000, but the amount of iodine in the thyroids of the animals hardly varied over the whole period.

Moreover, the amount of iodine in the thyroids from the "Keytah" sheep was not appreciably different from that in the glands from the adjoining station of "Boonaldoon," where no iodine was given. This would seem to be additional proof that the natural pasture contained a sufficiency of iodine, and that feeding iodine-containing licks was unnecessary.

We would like to take this opportunity of thanking all the pastoralists who have sent us thyroid glands and information about sheep, pastures, and so on, particularly Messrs. R. G. Beggs, H. Bouilly, D. E. Donkin, E. D. Ogilvie, H. W. Seager, A. F. Sutton, and F. H. Tout.

An Experiment on the Effect of an Iodised Lick on the Growth and Wool of the Australian Merino Sheep.

By E. W. L. Lines, B.Sc.*

(With a note on soil types by R. G. Thomas, B.Sc.*)

1. Introduction.

Among the investigations projected when the Division of Animal Nutrition was formed was an inquiry into the effects of specific mineral deficiencies. The possibility that iodine deficiency in some districts would upset thyroid function sufficiently to restrict wool growth was considered, and the following programme of investigation was drawn up:—

- (1) An examination of the thyroids of sheep collected throughout the year in several districts—(a) to establish a standard iodine content, and (b) to study seasonal variations under usual pastoral conditions.
- (2) A determination of the effect of feeding iodine in districts where a shortage was suspected.
- (3) The effect of partial and complete thyroidectomy on wool and body growth [Robertson (1929)].

This paper deals with the result of an experiment conducted under the second section of the programme. The results obtained under the first section have been published by Dawbarn and Farr (1932), and those of the third by Marston and Peirce (1932).

From examination of the thyroid glands collected in 1928 in the Moree district of New South Wales, Robertson opined that sheep in this area might have insufficient iodine in their diet. He therefore decided to test the influence of iodised licks on sheep depastured in this district.

In 1928, a field-station was established by the courtesy of E. D. Ogilvie, Esq., on his property, "Keytah," situated about 25 miles west of Moree, in latitude 29 deg. 30 min. S., longitude 149 deg. 30 min. E.

A note on the geology, soils, and topography is published by my colleague, Mr. R. G. Thomas, simultaneously with this paper.

Climate and Pasture at "Keytah."

The Moree district, in which this property is situated, has a mean rainfall of 21 inches. The district is about 230 miles from the coast, and lies between the regular orbits of the summer monsoonal rains and the regular winter rains of the southern part of Australia. "Coastal" rains are cut off by the New England mountains, some 5,000 feet high. In good years, the district receives both summer and winter rains, but in unfavorable years it may get neither, and the pastures fail completely unless natural irrigation from flooding of the Gwydir River occurs, following on heavy rains in the mountains to the eastward. As more than half the property is subject to this flooding several times a year, it is possible that the soil receives more moisture from this source

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in some years than it gets from local rainfall. These conditions probably have a marked effect on the botanical composition and nutritive value of the pasture. In Mr. Ogilvie's opinion, sheep do not do as well on country subject to flooding as the amount of herbage there would lead an experienced flock-master to expect.

The pasture plants which grow after rain or flooding vary according to the time of year. Summer growth is mainly grasses, *Panicum* spp. and *Calamagrostis* spp. are dominant; Mitchell grass (*Astrebla* sp.), Flinders grass (*Iseilma* sp.) and "white top" (*Danthonia* sp.) also occur. In winter, the prevailing plants are "burr clover" (*Medicago denticulata*), "crowsfoot" (*Geranium pilosum*), and geranium (*Erodium cygnorum*). Some of the perennial grasses, particularly *Danthonia*, shoot after autumn rains. A small water plant, *Marsilea Drummondii*, known as "nardoo," grows during, and after, floods, and is eaten freely by stock.

Paddocks.

The experimental area consisted of two very similar adjoining paddocks each about 300 acres in extent; both contained some "sand ridge" and "black soil" country, and were representative of the surrounding country (Fig. 1). A drafting yard and sheep scales were provided near the fence dividing the paddocks.

Management.

The lambs were weighed and ear-tagged within 24 hours of birth, and were weighed thereafter weekly to the nearest 0.2 kg.

The experimental and control lots in the second experiment were made up by dividing the ewe lambs alternately as dropped.

To equalize any difference in the fodder, the two flocks, together with their respective licks, were alternated between the paddocks every four weeks. Water was supplied either by a stream of artesian water from a bore some 2,000 feet deep, or by surface water left after flooding of the Gwydir River. The former water contains a fair amount of dissolved salts, and may have influenced the appetite for salt.

A considerable number of individuals were "struck" by the sheep blow-fly during the experiments, but there is no indication of any preference between the two lots of animals.

Weekly notes were made of the condition of the sheep and of the fodder as judged by the husbandman, and also any sickly or fly-struck animals were noted.

2. First Experiment.

In September, 1928, observations were commenced on the growth of 100 lambs of mixed sexes, which, together with their dams, had access to the station lick containing about 370 γ * of iodine per gm. During gestation, the station lick had contained about 740 γ of iodine per gm.

In April, 1929, a second group of 100 lambs were born whose mothers had not had access to iodised lick during gestation, and they were offered "iodine-free lick" from one month old.

Good to fair fodder conditions prevailed until June, 1929. From this time onward, drought caused a steady deterioration of the pastures, and by February, 1930, the natural pastures had completely failed, and the experiment was abandoned.

* γ = one-thousandth of a milligram.

Growth.

Although born seven months apart, the growth of the two groups was similar, as is shown by Table I.

TABLE I.—GROWTH OF LAMBS AT “KEYTAH” IN 1928 AND IN 1929.
BODY WEIGHT OFF PASTURE, IN KG.

Weeks of age	21	35	46
Iodised lick ♂ (males)	26.5 kg.	35.0 kg.	45.0 kg.
♀ (females)	24.5	31.5	40.0
Iodine-free lick ♂	26.5	35.0	..
(Controls) ♀	24.5	31.0	..

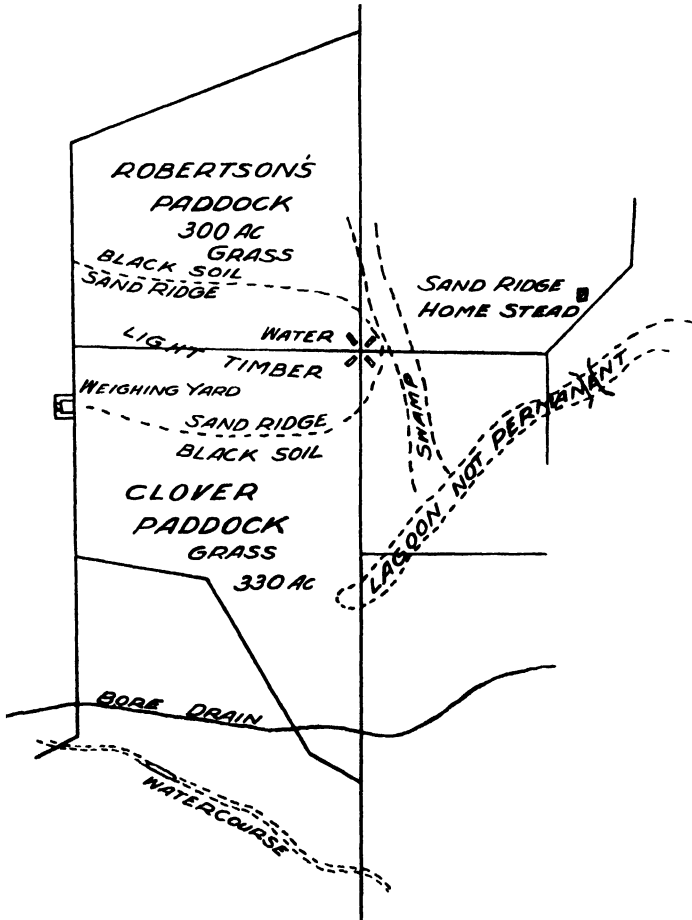


FIG. 1. Layout of experimental paddocks, “Keytah,” 1928-31

The control lambs were somewhat lighter in weight than those getting iodised lick, until the curves crossed at 21 weeks old. At 35 weeks old the curves again crossed. After this age, the drought upset all comparisons.

This experiment was unsatisfactory because—

- (a) the difference in birth date prevented the control being a true one, and
- (b) the experiment was interrupted by drought.

3. Second Experiment.

During the middle of 1930, good rains were received, and another experiment was commenced.* Sufficient ewes to provide 220 ewe lambs were placed at the disposal of the Division from those mated to lamb in September, 1930. Prior to lambing, these animals had had access to a station lick containing about 100 γ of iodine per gm.

As is usual after a drought has broken, the fodder conditions were particularly good, and remained so until mid-November. From November onward, the pastures steadily deteriorated until further rains were received at the beginning of March, 1932, after which the fodder conditions were excellent. During June and July, 1931, flood waters confined the sheep to restricted areas, and the available fodder was indifferent in quantity and quality until the water receded.

Lick Intake.

On "Keytah" it is customary to give the sheep a salt "lick" containing iodine. In September, 1928, the station lick consisted of—

Salt	..	..	200 lb.
Bone meal	..	..	25 "
Superphosphate	..	..	25 "
Ground sulphur	..	..	6 "
Ferrous sulphate	..	..	4 "
Potassium iodide	..	..	2 oz. (= 374 γ of iodine per gm.).

This lick was used throughout as "iodised lick."

For "iodine-free lick," a mixture containing the same proportion of mineral salts was made up from Merck's G. R. and British Drug House's A. R. chemicals.

Lick consumption was ascertained each week from the difference between the weight of lick supplied and the amount left in the troughs, and dividing the consumption over the number of animals in the paddock, including lambs.

The iodine requirement of the sheep was not known, but, from Marine's experiments on school children in central United States of America, it was assumed that a daily dosage of 0.5 to 1 mg. of iodine would be sufficient. Enough potassium iodide was therefore put in the lick to ensure that this dose was present in the sheep's average intake of lick. Subsequently, Orr and Leitch (1929) published their computation of 400 to 2,000 γ of iodine as the ordinary intake of sheep on good Scotch pastures, which coincides with the estimate calculated from Marine's data.

It is impossible to foretell just how much lick an animal will eat. The appetite for licks containing phosphate and salt is affected by the state of maturity of the herbage, being much greater in the autumn than in spring. Richardson et al. (1931) have shown that the phosphate

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content of Australian natural pastures falls rapidly as the plant matures and sheds its seed. At other times, the appetite for salt is the controlling factor, and this may be influenced by the amount of dissolved salts in the drinking water available.

In the first experiment, during which the fodder conditions varied for the most part from "only fair" to very poor, the animals consumed both licks at the rate of 700 gm. per head per year. In the second experiment, when "good" to "excellent" fodder was available, little lick was eaten (Fig. 2), and the consumption was confined to two periods of poor fodder conditions. The intake over the time when lick was being eaten was at the rate of 520 gm. per head per year. The mean intake over the whole period of the second experiment, i.e., from birth to a mean age of 47 weeks, was—

Iodised lick—0.5 gm. per head per day containing 185 γ of iodine.

Iodine-free lick—0.6 gm. per head per day.

As the intake of lick did not differ significantly as to date or amount between the two lots, it seems that the iodine content had no effect on the appetite for lick.

Growth.

The growth of the experimental and control lambs in the second experiment is shown in Fig. 2, using the method of Robertson and Ray (1925) in which "the increase of weight with time is represented by an area of which the middle point at any given age is the ascertained average weight, and the width of the area is twice the 'probable error' of the average."

These animals did not grow quite as well as those of the first experiment. Attacks by the blow-fly were severe during the latter half of the year, and the lower average live weight is partly attributable to this cause.

In the graph, the rainfall, fodder conditions, and intake of lick over the duration of the experiment are shown.

By the end of the experiment, when their average age was 47 weeks, 96 and 92 lambs were surviving from the two lots of 100 new-born lambs put on "iodine-free" and "iodised" lick, respectively.

Wool.

The wool shorn from each animal was carefully sorted and weighed. The individual weights were obtained for "fleece," "pieces," and "bellies." The yield of each individual fleece was judged, after "skirting," and that of the bellies, pieces, and locks in bulk. The "locks" of each lot were weighed together. The figures so obtained were used to compute the production of clean scoured wool of each individual.

MEAN WOOL PRODUCTION PER HEAD—ALL ♀ SECOND EXPERIMENT.

—		Greasy.	Clean.	S.D. Clean.	S.E. of Mean.	Mean Age.
		Lb.	Lb.	Lb.	Lb.	Weeks.
Iodine-free lick	..	7.51	3.592	0.398	0.041	47
Iodised lick (No. 2)	..	7.56	3.595	0.367	0.040	47

Mean and Standard Deviation computed from individual variates.*

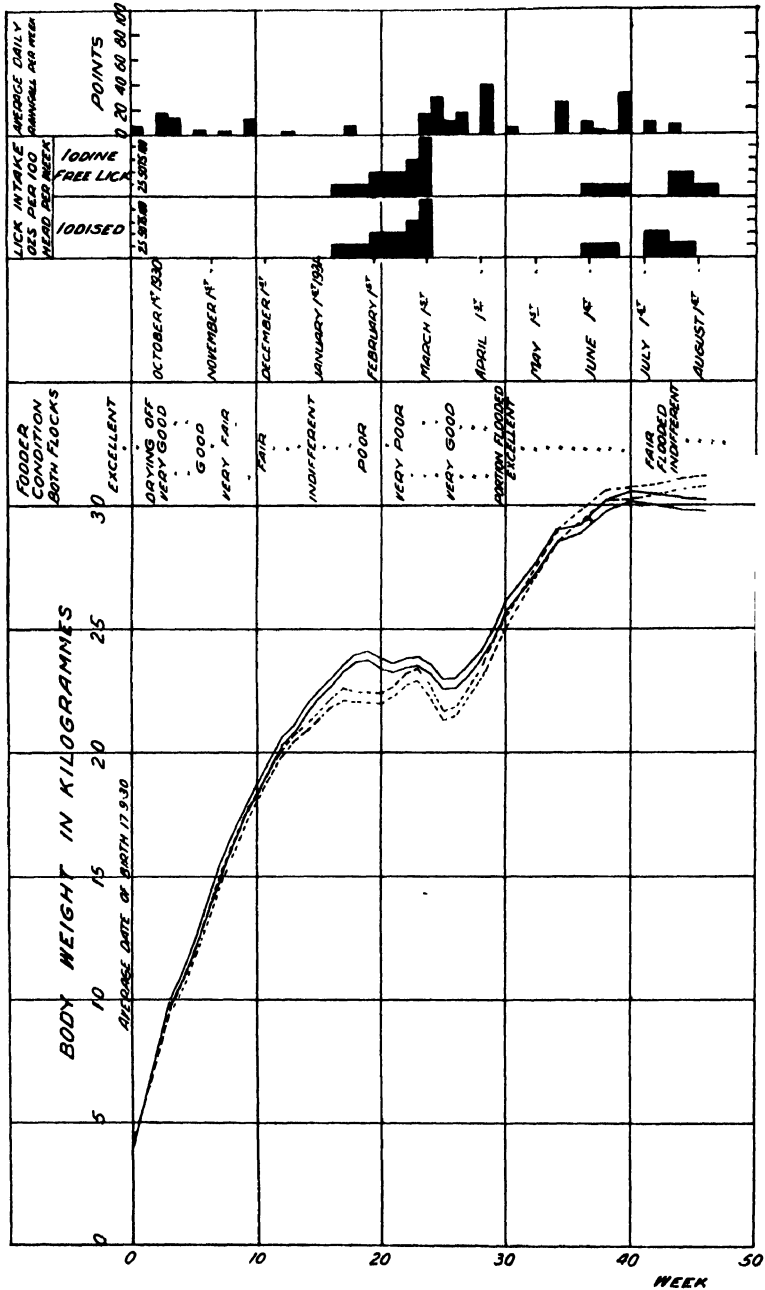


FIG. 2. Chart showing the growth, lick intake, &c., of the ewe lambs used in the experiment commenced in 1930. The weights of those receiving the iodised lick are indicated by the broken lines. The weights of the control group which received an iodine free lick are indicated by the unbroken line

DISTRIBUTION OF VARIATES. POUNDS OF CLEAN-SCOURED WOOL.

Class mean ..	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1
Iodine-free ..	1	2	5	14	7	14	28	12	5	4	3	0	1	0
Iodised lick ..	0	1	4	7	19	17	19	11	9	3	0	1	0	1

DISTRIBUTION OF ESTIMATED SPINNING COUNTS.

Spinning count ..	..	60's	60/64's	64's	64/70's	70's
Iodine-free ..	..	21	11	48	6	10
Iodised lick ..	..	9	16	51	11	1

The close agreement between the means of the body weights and of the wool clips is unusual, especially as the distributions of the variates tended to be "platykurtic."* The yearly culling of animals below a certain standard of production and the retention of the higher producers would tend to cause a distribution which was not "normal" in the statistical sense. This latter effect was not due to age at shearing, as the mean wool production of the younger half of each group did not differ significantly from that of the older.

4. Conclusions.

Increasing the intake of iodine by an average of 185 γ per day for 47 weeks had no significant effect on the growth or wool production of lambs at "Keytah," New South Wales. Owing to variations in the pasture during the second experiment, lick was eaten during nineteen weeks only, so that the average intake was much less than that in the first experiment, which was 720 γ iodine per day. However, as 185 γ per day is three times that calculated by v. Fellenberg (1926) to be the requirement of the growing child, the lambs should have responded definitely thereto were they suffering from any insufficiency of iodine.

This conclusion is supported by the result of analyses by Dawbarn and Farr (1932) of 171 glands collected from this district during the currency of these experiments. They found that the average iodine content of the thyroids of 101 sheep receiving iodised lick at "Keytah" (D_1 series) was 0.60 per cent., and that of 70 glands from "Boonaldoon," a similar adjoining property† (D_2 series), was 0.55 per cent. This difference is not significant—using the terminology of Fisher (1930)— $t = 1.83$, $n = 168$ and P lies between 0.10 and 0.05. The mean for some 500 Australian glands which they analysed was 0.56 per cent. iodine. It therefore appears that the iodised licks fed to the D_1 series of sheep at "Keytah" failed to alter the iodine content of their thyroids significantly.

* Here used according to K. Pearson, meaning that the variates tended to be distributed further from the mean than is normal.

† But where no lick was fed.

5. Acknowledgments.

The author's thanks are due to E. D. Ogilvie, Esq., and to Messrs O. K. Samuel and V. Curtin, who made the field measurements; to Mr. G. W. Bussell, who prepared the graphs; and last, in point of time, to Sir Charles J. Martin for his help and criticism during the preparation of this paper.

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Appendix.

NOTES ON SOIL TYPES AT "KEYTAH."

By R. Grenfell Thomas, B.Sc.

The soils at "Keytah" form two main groups, the "sand-ridge" soils and the "black soil" of the plains. The vegetation of these two types is quite distinct, and the junction between them sharp and well defined. The black-soil plains are usually quite devoid of timber, but support an abundant growth of grasses, whereas the sand ridges are often quite heavily timbered. In many instances, there appears to be a definite zoning of timber on the sand ridges. The central and higher portions may support a tree association comprising sandalwood, wilga, &c., to belah, pine, and beefwood. The outer edges of the sand ridges near the black soil usually show a well-defined zone of box gum, while at the actual junction of the water-course country with the sand ridges, coolibah trees are almost invariably present.

The central sand-ridge soils often show a bare clay-pan surface devoid of grass and timber. The subsoils of the sand ridges are generally hard brown clay, carrying nodules of gypsum and calcium carbonate.

The black-soil plains show little change in character down to 27 inches below the surface.

The main features may be summarized as follows:—

- (1) The whole area has reached a condition bordering on base level as regards drainage.
- (2) The soils are almost exclusively transported alluvials derived from the highlands to the east. They range from early Post Tertiary to Recent.
- (3) The early alluvium consists largely of gravels and sands; the more recent alluvium is mostly made up of clays and fine silts, indicating a constant falling off in the transporting power of the western drainage system.

A Preliminary Survey of the Distribution of the Hookworm of Sheep in New South Wales.

By G. Kauzal, D.V.Sc.,* and N. P. H. Graham, B.V.Sc.†

Up to the last few months of the year 1932, Mr. Graham was an investigator located at the F. D. McMaster Animal Health Research Laboratory under the Australian Pastoral Research Trust—Empire Marketing Board scheme (see this *Journal*, Vol. 4, August, 1931, page 1933). At the request of the Trust, however, he was then transferred to the Trust, so that he is now a full-time officer of that body. His headquarters still remain at the McMaster Laboratory, but from time to time the Trust uses him to investigate particular problems that have been referred to it by its members. In between times Mr. Graham also assists with his former investigations. The work described in the article that follows was carried out in between periods of visits to individual stations made at the request of the Trust.—Ed.

1. Introduction.

The first record of the occurrence of the hookworm of sheep, *Monodontus trigonocephalus*, in Australia was made by Gordon (1932) in sheep examined at the Homebush Abattoirs. In view of the pathogenic importance of this species in other countries, it was considered desirable to determine, with as much accuracy as possible, its distribution in New South Wales. A survey was carried out by the routine examination of sheep by one of us (G. K.) at the Metropolitan Meat Industry Board's Abattoirs, Homebush Bay, and the Sydney Meat Preserving Company's Works, Auburn, while examination of sheep in the field and at local slaughter yards was also carried out by one of us (N. P. G.).

As a result of the abattoir examination, 39 cases of infestation with *M. trigonocephalus* have been found, out of a total of 456 sheep examined at the abattoirs, giving a percentage of 8.6. In general, it was found that the individual infestations were light, but invariably accompanied by marked macroscopic lesions, mainly in the form of haemorrhage into the mucous membrane of the small intestine. While the average degree of infestation was 21.9 worms per sheep, in a few instances up to 100 worms were present.

As a result of the local examination of sheep on individual properties and at small country slaughter houses, eighteen further cases of infestation were found out of a total of 58 sheep examined. In the majority of these, infestation was extremely light, and in some of them only a single worm was found.

2. Distribution of the Parasite.

As a result of the routine examination of sheep at Sydney Abattoirs, the hookworm was found to occur in sheep from five Pastures Protection Districts, namely, Merriwa, Singleton, Upper Hunter, Tamworth, and Armidale. Local examinations confirmed the finding of the parasite

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† Veterinary Officer, Australian Pastoral Research Trust.

in the first four of the above districts, and also revealed its presence in the Glen Innes Pastures Protection District. In infestations found in this district, however, only a single worm was present in each of two sheep.

It has been found, where the actual properties from which the infested sheep came could be determined, that all of these, with one exception, lay on the eastern side of the Great Dividing Range. In one district in particular, this was rather strikingly brought out, since on three properties lying to the west of the Dividing Range no cases of infestation were found, whereas on each property visited on the eastern side infestation occurred.

Though from the results of this survey it is indicated that *Monodontus trigonocephalus* is already well established and of common occurrence, since out of a total of 514 sheep examined from all sources, 57—i.e., 11.1 per cent.—were found infested, it is not considered that this gives any real indication of the incidence throughout the State as a whole. So far as local examinations in the field were concerned, these were expressly concentrated on those districts in which the parasite had already been found to occur, while even at the Sydney Abattoirs there was a preponderance of sheep examined from the northern and central divisions of the State. So far as the survey has gone at the present time, the heaviest infestations and the greatest percentage of cases have come from the Upper Hunter and Singleton Pastures Protection Districts. A survey is at present being carried out by one of us (N. P. G.) embracing the southern part of the Central Tablelands and Southern Tablelands and slopes, in order to determine if possible whether the parasite is present in that part of the State. So far, there has been no evidence that it does occur to the south of the districts already found infested.

In conclusion, it may be mentioned that in other parts of the world the hookworm of sheep has been found to have a very wide distribution, and is by no means confined to warm and temperate zones. Cameron (1932) has pointed out that it is not uncommon in sheep and deer in the cold highlands of Scotland. If it can be determined that the parasite at the present time has a relatively limited distribution in Australia, it should be possible to concentrate on eliminating the present source of infestation before further expansion of its distribution occurs.

3. References.

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Parasitological Field Trials With Sheep.

Results at "Frodsley," Tasmania, and "Meteor Downs," Queensland.

The work, the results of which are given in the article that follows, forms part of the programme of investigations that is being undertaken by the Council's Division of Animal Health under the Australian Pastoral Research Trust—Empire Marketing Board scheme (see this *Journal*, Vol. 4, August, 1931, p. 133). The two trials reported on were carried out with the kind co-operation of Mr. K. Brodribb, of "Frodsley," Tasmania, and Major D. Donkin, of "Meteor Downs," Queensland, who have, at all times, greatly facilitated the experiments by supplying the use of the necessary land and experimental sheep.—ED.

I. Experiments at "Frodsley," Tasmania.

By I. Clunies Ross, D.V.Sc.,* and N. P. H. Graham, B.V.Sc.†

Summary.

1. Routine monthly treatment with carbon tetrachloride and copper sulphate led to no increase in wool or body weight in sheep mainly infested with small *Trichostrongylid* worms. It is known that these parasites are resistant to any known treatment.

2. There was, however, a marked improvement in wool quality in treated compared with untreated sheep, so that it is probable that treatment mitigates somewhat the adverse effects caused by these parasites.

3. Sheep on improved pasture, either with or without treatment, showed marked increase in body weight, and produced over 2 lb. more wool per head than the sheep on natural pasture, either treated or untreated. The only difference noted between treated and untreated groups on improved pasture was a slight improvement in wool quality in the treated sheep.

4. The wool of sheep run on improved pasture was estimated to give as high, or higher, percentage clean-scoured yield as that of any sheep on natural pasture.

5. The administration of sodium arsenite and copper sulphate in licks had no demonstrable effect in diminishing infestation with the large bowel parasites, *Chabertia ovina* and *Oesophagostomum venulosum*.

1. Introduction.

In 1931, the Council for Scientific and Industrial Research conducted a field trial on "Frodsley," in Tasmania, to determine the effects of various methods of medicinal treatment in controlling losses in sheep, supposedly due to helminth parasites. The results of that trial (see this *Journal* 5 : 31, 1932) indicated that, although parasitic infestation was principally due to small *Trichostrongylids* (*Ostertagia* spp., *Trichostrongylus* spp., and *Nematodirus* spp.), and large bowel parasites (*Oesophagostomum venulosum* and *Chabertia ovina*) all of which are known to be difficult to control, regular treatment with either carbon tetrachloride or copper sulphate not only lessened mortality, but led to some increase in wool and mutton production. Such increase, however, was not sufficient to produce either a satisfactory wool yield or mutton carcass.

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† Veterinary Officer of the Australian Pastoral Research Trust.

During 1932, a further trial was conducted, in order to confirm the findings of 1931, and, in addition, to see whether by means of pasture improvement, both with and without treatment, a satisfactory standard of wool and mutton production might be reached. It was also desired to experiment further with the use of a phosphatic lick against large bowel parasites. This lick also contained copper sulphate and sodium arsenite, and was one which Veglia (1928), in discussing the control of *Oesophagostomum columbianum*, had suggested as being of value. Finally, the value of oats as a supplementary feed for sheep, both with and without meat meal, was investigated, in view of the widespread use of the former as a sheep feed in Australia.

2. Details of Trial.

During the present trial, 210 cross-bred ewe lambs were employed, these being weaned at the commencement of the trial, at which time they were four to five months old. The lambs were each ear-tagged, and then were divided into seven groups, each of 30 lambs. Each group, except Nos. 6 and 7, was supplied with a basal phosphatic lick containing bone flour 45 parts, dicalcic phosphate 45 parts, and salt 10 parts.

Groups 1, 2, 3, 4, and 5 were run on natural pasture, at the rate of approximately 1 sheep to $1\frac{1}{2}$ acres. From month to month, each group was moved in rotation through five paddocks.

Groups 6 and 7 were run separately on improved pastures at the rate of $1\frac{1}{2}$ sheep to the acre, the paddocks being alternated each month.

The several lots were treated individually, as follows:—

Group 1.—Drenched at monthly intervals with 2 cc. carbon tetrachloride in 3 cc. liquid paraffin.

Group 2.—Drenched as in Lot 1, receiving also an addition to the basal phosphatic lick of sodium arsenite 1 part, copper sulphate 4 parts per 1,000 of the lick.

Group 3.—Drenched as in Lots 1 and 2, but also receiving a supplement of $\frac{1}{4}$ to $\frac{1}{2}$ lb. of oats per day from March to the end of October, the average consumption throughout being 6 oz. per head per day.

Group 4.—Drenched at monthly intervals with 50 cc. of a 1 per cent. solution of copper sulphate.

Group 5.—No medicinal treatment.

Group 6.—Medicinal treatment as in the case of Group 1.

Group 7.—No medicinal treatment.

In addition to the above seven groups, a group of a further 40 lambs, some of which were the culls of the mob, were run on unimproved pasture, under pasture conditions not strictly comparable with those of Lots 1 to 5. These were not drenched, but were given supplementary feeding with meat meal and oats, of which the quantity consumed will be detailed later, and the same medicinal supplements in the lick as in the case of Group 2. This lot may be designated *Group 8*, though no strict comparison can be made between it and the other groups.

At the beginning of the trial, the mean body weights of the several groups were as follows:—

Group 1.—	49.8036 \pm 0.8977 lbs.
Group 2.—	50.6000 \pm 0.7862 lbs.
Group 3.—	50.5333 \pm 0.7849 lbs.
Group 4.—	49.2167 \pm 0.8065 lbs.
Group 5.—	50.8333 \pm 0.8835 lbs.
Group 6.—	48.8667 \pm 0.7853 lbs.
Group 7.—	51.7333 \pm 0.6898 lbs.
Group 8.—	48.1842 \pm 0.6083 lbs.

Unfortunately, the statistical treatment of these group weights was not possible before the commencement of the trial, since Dr. Carr Fraser, in examining them subsequently for homogeneity, has found that Groups 6 and 7 were not statistically homogeneous, though each is homogeneous with all other groups. Group 8 has also been found by Dr. Fraser to be non-homogeneous with Group 7.

Climatic and Other Conditions during the Trial.—No rain was recorded in January after the first weighing and drenching of the several lots. In February, the rainfall was not recorded, but conditions continued to be very dry throughout this month, pastures drying off markedly in all lots, and being well eaten down in the improved pasture lots (Nos. 6 and 7). During the following ten months, the rainfall was as follows:—

March	..	..	..	4.21 inches.
April	..	..	..	2.25 "
May	..	..	..	0.72 "
June	..	..	..	3.60 "
July	..	..	..	2.50 "
August	..	..	..	4.25 "
September	..	..	..	6.00 "
October	..	..	..	3.35 "
November	..	..	..	1.00 "
December	..	..	..	1.51 "
Total	..	..	..	35.30 "

Owing to the topdressing with superphosphate of the paddocks of Groups 6 and 7 being delayed until March, no shoot of clovers and other herbage followed the March rains, and, owing to this and the depredations of rabbits, both lots lost markedly in weight, Group 6 suffering particularly. So serious was this, that from the 8th April to the 8th May, it was necessary to move both lots to another improved pasture paddock. From April onwards, however, there was a satisfactory response from these pastures, as is reflected by the steady gains in weight made by Groups 6 and 7 on being returned to them on 8th May, and onwards through the severe winter months. The year, as a whole, was considered a very favourable one for the district, and all lots did very much better than the corresponding groups in 1931.

Parasitic Infestation.—The type and degree of parasitic infestation in all groups was followed each month by culturing faeces taken from three sheep in each group selected at random when the sheep were mustered for weighing and drenching.

At the beginning of the trial, post-mortem examination showed the predominant infestation to be with small *Trichostrongyles*, mainly *Ostertagia circumcincta* and *Trichostrongylus* spp. (*T. instabilis*, *T. rugatus*, and *T. vitrinus*) while *Nematodirus* spp. were also numerous. The degree of infestation with *Nematodirus* sp. was rather difficult to compare with that of the other species, owing to developmental peculiarities of the larvae, and also the very poor egg-laying properties of this species. The larvae of large bowel parasites, considered to be chiefly *Oesophagostomum venulosum*, comprised a relatively large percentage of larvae in cultures (0 to 25 per cent.), while some *Chabertia ovina* were also present.

Haemonchus contortus, which some years previously was said to have been an important parasite on this property, was found, as in 1931, to be present to only a very slight degree, whether in treated or untreated lots. *Cooperia* spp. also comprised a very low percentage of larvae in the several lots.

The degree of infestation as shown by faecal culture did not appear to suffer any marked variation, but this method of determining such variation was frequently unsatisfactory, owing to the faeces being very soft and even diarrhoeic, particularly following the heavy rains in August and September.

3. Results Obtained.

Though certain sheep died in each of Groups 2, 3, 4, 5, and 6, it was only possible to carry out detailed post-mortem examinations of two of these, No. S 177 from Group 6, and S 76 from Group 3.

S 177 (Group 6) died on 23rd July, and the viscera were kindly examined by Mr. D. T. Oxe, B.V.Sc., of the Tasmanian Department of Agriculture, and all parasites were collected. Infestation with parasites was found to be very light, the species present being *Ostertagia circumcincta*, *Trichostrongylus* spp., and *Nematodirus filicollis*.

S 76 (Group 3) was seen to be losing condition rapidly during July, and in August was forwarded by Mr. Brodribb to Mr. Oxe for examination. The animal was destroyed by Mr. Oxe, the worms in the stomach were counted, and those in the small intestine forwarded to this Laboratory. After counting several samples totalling over 1,000 worms in suspension, it was estimated that there were approximately 30,000 present in the stomach and small intestine, of which approximately equal numbers were *Trichostrongylus* spp. and *Nematodirus* spp. At the same time as this sheep was seen to be losing condition markedly, S 117 (Group 4) was also found to be similarly affected, and at the September weighing it had lost 11 lb. weight since June. It was sent to Mr. Oxe in Launceston, but recovered on receiving artificial feeding. Probably, this sheep would have been found to be as heavily infested as S 76.

At the September weighing, it was found that in each of Lots 1 to 5, a number of sheep had lost over 6 lb. weight. The very heavy infestation of S 76 and sheep treated monthly with carbon tetrachloride illustrates the relative inefficiency of this treatment to control small *Trichostrongyles*.

Mortality.

During the twelve months of the trial, the mortality in the various groups was as follows:—

Group 1	..	..	..	0
Group 2	..	..	..	2
Group 3	..	..	..	2
Group 4	..	..	..	1
Group 5	..	..	..	3
Group 6	..	..	..	1
Group 7	..	..	..	0

As has been mentioned, autopsies were performed only on S 177 and S 76. In the first of these, the cause of death could not be determined, but it did not appear to be due to parasitism, infestation being extremely light. In the case of S 76, death could certainly be considered to be due to parasitism (H. McL. Gordon, in unpublished work, has found an infestation with 9,000 to 10,000 *Trichostrongylus instabilis* sufficient to cause death in lambs three to four months old, running with their mothers, and receiving hand-feeding in addition). Though the higher mortality is in no way significant, it is of interest to note that more animals died in the untreated control group than in any other—a similar result to that noticed in the 1931 trial, when the control group suffered by far the heaviest mortality.

Consumption of Lick.

It is to be remembered that Groups 1, 3, 4, and 5 received a basal phosphatic lick, comprising dicalcic phosphate 45 per cent., bone flour 45 per cent., and salt 10 per cent. Consumption per lamb per day was negligible from January to March, but from April to October, consumption varied markedly from group to group. From October onwards, consumption of lick in these lots again became negligible, except in Lot 3, in which it averaged 6.2 gms. per day. The average daily consumption per sheep from April to October was as follows:—

Group 1,	2 gms.	Maximum in any month,	3.45 gms.
Group 3,	11.6 gms.	Maximum in any month,	17.3 gms.
Group 4,	2.4 gms.	Maximum in any month,	3.45 gms.
Group 5,	1.9 gms.	Maximum in any month,	2.9 gms.

It is seen that Group 3, which received an average daily supplement of 6 oz. of oats per head per day from April to November, consumed very much more of the lick than any of the other basal lick groups.

The consumptions of lick per head per day by Groups 2 and 8, which received the same basal lick as the other groups, but with the addition of medicinal supplement in the form of sodium arsenite 1 part, and copper sulphate 4 parts per 1,000, were as follows:—

Group 2,	0.8 gms.	Maximum in any month,	1.9 gms.
Group 8,	8.1 gms.	Maximum in any month,	12.8 gms.

Here again, as in the case of Group 3, it appears that the feeding of an oat and meat supplement to Group 8 resulted in greatly increased consumption of minerals. This very much higher consumption of lick by both lots receiving supplementary feeding in the form of concentrates is of considerable interest.

The abnormally low consumption of lick by Group 2 is thought to be due to the very bitter nature of the drugs added. Groups 6 and 7 on improved pasture received no licks.

Consumption of Food Supplements.

Group 3, which received a daily ration of oats varying from $\frac{1}{2}$ lb. to $\frac{3}{4}$ lb. per head per day from April to November, consumed in all 80 lb. per head. The 40 sheep in Group 8, which received the meat and oats supplement, consumed 120 lb. of oats per head, over the same period, and 19 lb. of meat meal from June to November.

Body Weights.

The accompanying graphs* illustrate that all four lots on natural pasture without supplementary feeding exhibited a negative growth curve until the spring shoot occurred, as seen at the October weighing. The loss of weight tended to be most severe in the case of the control Group 5. In the case of Group 3, receiving the oats supplement, some slight gain occurred during the negative phase of the other groups; this also occurred in the case of Group 8, receiving the oats and meat meal supplement. At the time of shearing on 23rd November, the gains in weight per head in the several groups, exclusive of the fleece weights, were as follows:—

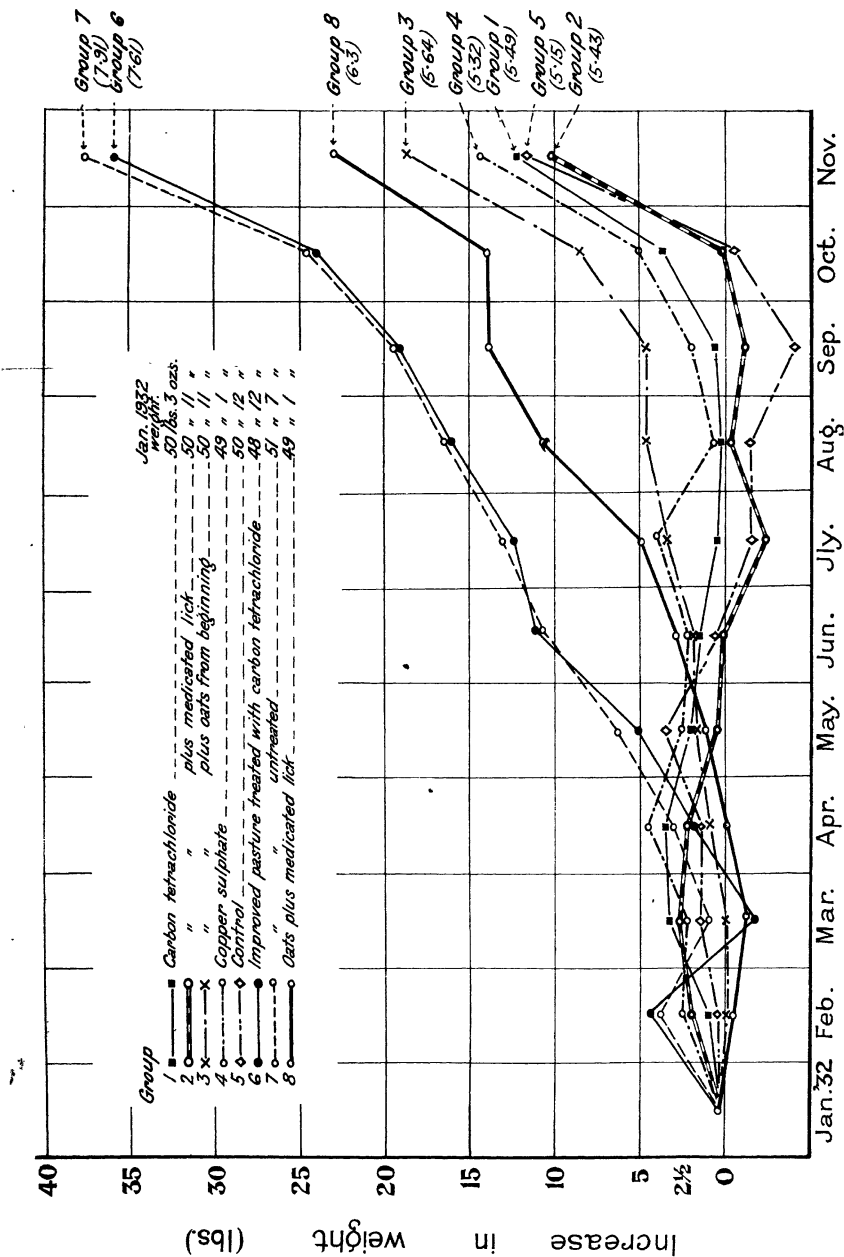
Group 1	..	..	6.8 lb.
Group 2	..	..	5.7 lb.
Group 3	..	..	15.0 lb.
Group 4	..	..	7.6 lb.
Group 5	..	..	8.2 lb.
Group 6	..	..	31.9 lb.
Group 7	..	..	33.3 lb.
Group 8	..	..	21.0 lb.

The final weighing of all groups was made on 14th and 15th January, 1933, after completing twelve months of the trial. The final weights per head and the gains since the beginning of the trial were as follows:—

Group 1—Average weight,	65.25 lb.	Gain,	16 lb.
Group 2—	..	67.0 lb.	.. 16.4 lb.
Group 3—	..	79.18 lb.	.. 28.65 lb.
Group 4—	..	69.7 lb.	.. 20.49 lb.
Group 5—	..	69.33 lb.	.. 18.5 lb.
Group 6—	..	93.57 lb.	.. 44.7 lb.
Group 7—	..	98.95 lb.	.. 47.2 lb.
Group 8—	..	79.31 lb.	.. 31.12 lb.

Dr. Carr Fraser has found that the differences between Groups 1, 2, 4, and 5 are not significant, and it appears, therefore, that medicinal treatment on natural pasture resulted in no gain in body weight when compared with the untreated control Group 5. This lack of indication of any beneficial effect from medicinal treatment as far as body weight is concerned is probably due in part to the fact

* Based on monthly weighings, those in November being taken before shearing.



Graphs showing gains in weight of groups of experimental sheep at "Frodley," Tasmania, during 1932. Each group was given a different treatment against internal parasites. The figures in brackets under the group numbers on the right denote average wool weights per head.

that the helminth species present were mainly *Ostertagia* spp. *Trichostrongylus* spp., *Nematodirus* spp., *Chabertia ovina* and *Oesophagostomum venulosum*, against none of which has any satisfactory treatment been devised. In contrast, Groups 3 and 8, on natural pasture with supplements, showed definite increases in the weight gained, but these, in view of the high consumption of expensive supplements, are relatively slight. The difference between these two groups, in spite of the fact that one received a meat meal supplement and consumed more oats, is not significant.

In the case of Groups 6 and 7, on improved pasture, at a rate of stocking double that of the natural pasture groups, both groups showed very much greater gains than any natural pasture groups, but again there is no significant difference between treated and untreated, and the untreated group actually made a greater average weight gain. As has been mentioned, owing to lack of homogeneity at the beginning of the trial, there is no logical basis for comparison of these groups, although each is comparable with Groups 1, 2, 3, 4, and 5.

Wool Weights.

All groups were shorn on 23rd November. Each individual fleece was weighed and classed for general quality, count, length of staple, and estimated clean-scoured yield. The average wool production in each group was as follows:—

Group 1	..	..	5.49 lb.
Group 2	..	..	5.43 lb.
Group 3	..	..	5.64 lb.
Group 4	..	..	5.32 lb.
Group 5	..	..	5.15 lb.
Group 6	..	..	7.61 lb.
Group 7	..	..	7.91 lb.
Group 8	..	..	6.3 lb.

The differences shown in wool weight between Groups 1, 2, 3, 4, and 5 are not significant. As in the case of body weight, medicinal treatment, even combined as in the case of Group 3 with supplementary feeding with oats, resulted in no significant increase in wool production.

Group 8, which received meat meal in addition to oats, cut slightly more wool than the natural pasture groups, but from an economic stand-point the increase was unimportant in relation to the high cost of the supplements fed.

The two improved pasture groups showed a very marked increase over any of the natural pasture groups, the difference between the treated and untreated lots not being significant, but again the untreated lot produced a slightly higher average yield.

Quality of Fleece.

In contrast to the lack of any significant difference in the amount of wool produced in the treated and untreated lots, a marked difference was shown in the quality of the wool of the treated when compared with the untreated natural pasture groups. All groups on natural pasture and not receiving supplements showed a proportion of tender.

wools, but this varied in the several groups, and was very much higher in the case of the untreated controls. The percentage in each group was as follows:—

Group 1	..	..	6 per cent.
Group 2	..	..	10.7 per cent.
Group 4	..	..	17.9 per cent.
Group 5	..	..	58.3 per cent.

No tender fleeces occurred in Group 3, which received the oats supplement in addition to medicinal treatment, but 9 per cent. occurred in Group 8. None of the sheep in Groups 6 and 7 showed any tender fleeces. In spite of this, according to the classer's estimate, the wool of Group 6 was considered to be definitely superior in quality to that of Group 7, it being estimated that it was of at least 5 per cent. higher value.

The apparent influence of treatment in improving wool quality by decreasing the number of tender fleeces indicates that quality of wool may be a more sensitive indicator of adverse conditions than the weight of fleece produced, just as in the previous trial (Clunies Ross and Graham, 1932) there were indications that under improved pasture conditions fleece weight was a more sensitive indicator of the effects of internal parasitism than body weight.

Effect of Improved Pasture on Fleeces.

(i) *Count.*—The fleeces in each group were classified into the following classes:—56 to 56-58, 58 to 58-60, and 60 to 64. It was found that the improved pasture groups showed a definite, though relatively slight, lowering in count when compared with the natural pasture groups, whether treated or untreated, or whether receiving supplements.

In all natural pasture groups, the largest class of fleeces fell within the 60 to 64 group. In the case of Groups 6 and 7 (improved pasture) on the other hand, the largest group of fleeces fell in the 58 to 58-60 class.

Groups 3 and 8, receiving supplements, produced as high a percentage of 60 to 64 fleeces as natural pasture groups without supplements.

It is again necessary to stress the fact that the commonly held idea that a relatively slight lowering of count, such as occurred on improved pasture in the present trial, and in that previously reported (Clunies Ross and Graham, *loc. cit.*) is not necessarily any indication of lowering in value of the fleece. It is known that a well and evenly-grown 58's wool may have as high a spinning value as a poorly grown 64's, and in this connexion the proportion of tender fleeces in all natural pasture groups without supplementary feeding is contrasted with the 100 per cent. of sound fleece in the improved pasture groups.

(ii) *Estimated clean-scoured yield.*—The estimated clean-scoured yield is based solely on an expert classer's estimate, and while this estimate may not be exact so far as the actual yield is concerned, there is no reason to doubt that it does give an accurate indication of the relative yields of the several groups. As in the trial quoted above, it was again found, contrary to commonly held views, that the improved

pasture groups gave as high a percentage of high-yielding fleece (66 to 68 per cent.) as any of the other groups. In fact, in the case of Group 6, there was a higher percentage than in any other group.

In this connexion, it might be mentioned also that the work of Marston (1932) also shows that supplementary feeding, even when leading to very marked increase in wool production, does not lead necessarily to a lessening of clean-scoured yield.

Parasitism at the End of the Trial.

At the end of the trial in January, a number of sheep in each group (except Group 1) were examined post-mortem, to determine the degree and type of parasitism present. Though this examination was designed to determine any gross variation in the degree of infestation in the several groups, it had the special object of determining whether the medicinal supplements added to the licks in Groups 3 and 8 had any effect in reducing the numbers of large bowel parasites (*Chabertia ovina* and *Oesophagostomum venulosum*) in these groups. So far as the general parasitism was concerned, it was found to be extraordinarily light in all groups. Apparently, the heavy infestations suffered by some sheep in the late winter and spring (e.g., S 76) had been very largely thrown off, even by untreated sheep, as a result of improved nutrition.

Infestation with *Haemonchus contortus* was extremely light, not more than three worms being found in any sheep in any group, even in the control untreated Group 5. *Ostertagia* and *Trichostrongylus* sp. were present in the majority of sheep, whether treated or untreated, but there was no significant difference in the numbers present in any group, with the possible exception of Group 7, in which two sheep were entirely negative. *Nematodirus* was absent in all sheep, with the exception of one animal in Group 2 in which only a very few individuals were present.

In the case of the large bowel parasites, comparison was first made between the sheep in Group 8, in which the consumption of lick containing medicinal supplements had been high, and in the control untreated group. In this group, of which six animals were killed, the average number of *Chabertia ovina* was 3.66, and of *Oesophagostomum venulosum* 24.33. In Group 5, of which five animals were killed, the average number of *Chabertia ovina* present was 7.0, and of *Oesophagostomum venulosum* 24.2. There is no significant difference, therefore, in the number of large bowel parasites present in the untreated control group, and the group receiving and consuming large amounts of medicated supplements in the form of a lick. There is no evidence, therefore, that such supplements had any effect on the large bowel parasites.

It might be noted, however, that the other natural pasture groups examined, Groups 2, 3, and 4, had a considerably larger average number of these parasites than the control untreated group on natural pasture. In the case of Group 2, which also received medicinal supplements, but of which the average consumption was extremely low, the average number of *Chabertia ovina* was 1, and of *Oesophagostomum venulosum* 42.

Only two sheep were found entirely free both from *Chabertia ovina* and from *Oesophagostomum venulosum*, these being in Group 7. .

4. Discussion.

The present experiment offers some confirmation of that of 1931, in that, though 1932 seasonal conditions were much less severe, so that there was no differential mortality rate nor differences in production of wool or mutton, definite beneficial effects of medicinal treatment against small *Trichostrongyles* were made evident by the much better wool quality of the treated sheep on natural pasture, compared with the control group (Group 5). At the time of shearing in November, in the opinion of the wool-classer, which was confirmed by Mr. D. T. Ozer, B.V.Sc., Group 5 was quite obviously the most unattractive of all groups in general appearance, and this was borne out by the analysis of the fleeces showing the much greater number of tender fleeces in this group.

In spite, therefore, of the known inefficiency of treatment with either carbon tetrachloride or copper sulphate against the small *Trichostrongyles* of sheep, it is evident that such treatment may serve to mitigate their effects. It does not make less necessary the development of more satisfactory methods of treatment and control than are at present available.

The improved pasture lots, Groups 6 and 7, indicate that not only is very great improvement in wool and mutton production possible by improved pastures, but that with adequate nutrition the effects of parasitic infestation, under the conditions obtaining in the present trial, become apparently negligible, as gauged by wool and mutton production in treated and untreated groups. Compared with the best average wool production of any natural pasture group without supplements (Group 1), namely, 5.49 lb., both improved pasture groups produced more than 2 lb. per head more, and, at twice the stocking per acre, 9 lb. more per acre. In addition, compared to the best gain in body weight on natural pasture without supplement, they produced over 20 lb. more in liveweight per head, or over 115 lb. more per acre. In addition, a survey of paddocks 6 and 7 at the beginning of the summer showed that they could have carried an extra lamb per acre.

The use of medicinal supplements in licks in the group (Group 8) in which consumption averaged over 8 gms. per head per day throughout the trial was not found to lead to any decrease in the number of *C. ovina* or *Oc. venulosum* present, when compared with the untreated control (Group 5). Consumption of medicinal supplements in the groups would be equivalent to approximately 240 mg. (4 grains) of sodium arsenite per month, and 960 mg. (16 grains) of copper sulphate per month, or double the dose of these drugs usually used in combination in routine treatment of sheep. The supplements are even less likely to prove effective under Australian field conditions, in that, when used, lick consumption appears to be decreased owing to the bitter nature of the drugs. Thus, in Group 2, which did not receive any food supplement, the average consumption was only 0.8 gms. per day. The high consumption in Group 8 appeared to be associated with the feeding of food supplements.

The results in the present trial do not bear out the indications of the 1931 trial that these drugs administered in the lick had lessened infestation with the large bowel parasites, but confirm experimental

evidence (Clunies Ross, 1932) of the futility of endeavouring to control parasitic infestation by adding medicinal supplements to licks and drinking water.

So far as the food supplements are concerned, the use of oats at the rate of 6 oz. per head per day from April to November (seven months), costing approximately 5s. per head, led to a disappointing increase in body weight, and no significant increase in fleece weight. However uneconomic such continuous feeding might be, it was to be expected that at least some increase in wool production might have resulted. It is true that all fleeces in this lot were sound, whereas 58 per cent. of fleeces in Group 5 (control untreated) were unsound. This, however, was the only definite value of the supplement so far as wool production was concerned. In this connexion, it must be remembered that oats are very commonly fed as a supplement to sheep in Australia, in Western Australia up to 1 lb. per head per day being given for months at a time in certain districts. It would appear very doubtful whether feeding on such a scale is justifiable, and whether equally good results might not be obtained much more economically such as by other supplements, improvement of pastures, &c.

Group 8, which received an average of 9 oz. oats per head per day from April to November, and 1.9 oz. of meat meal from June to November, at a total cost of approximately 9s. 3d. per head, showed no significantly greater increase in weight than Group 3, but produced a significantly greater amount of wool (6.3 lb. per head, compared with 5.6 lb. in Group 3). Again, the gain in body and wool weights was entirely insignificant in relation to the cost of the supplements fed.

5. References to Literature.

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2. Experiments at "Meteor Downs" during 1932.

By I. Clunies Ross, D.V.Sc., and N. P. H. Graham, B.V.Sc.

Summary.

1. Treatment with carbon tetrachloride under the conditions obtaining through this trial led to no increase in body weight in the treated animals as compared with the untreated animals.
2. Treatment with carbon tetrachloride led to no increase in fleece weight, nor significant difference in wool quantity.
3. It is thought that the very low rainfall contributed largely to the lack of evidence of harm caused by parasites.

1. Introduction.

The field trial on "Meteor Downs" was devised to supplement that carried out in 1931, which, unfortunately, had to be abandoned owing to drought conditions, after having been in operation for only a few months. The objects of the trial were:—

1. To determine the effect on worm infestation and on wool and mutton production of drenching at monthly intervals with carbon tetrachloride.

2. To determine whether, when administered in conjunction with monthly drenching with carbon tetrachloride, the addition of sodium arsenite and copper sulphate to the basal phosphatic lick supplied to all groups would effect some satisfactory measure of control of *Oesophagostomum columbianum* (the nodule worm) in the large bowel, which is known to be resistant to ordinary anthelmintic medication.

3. Whether the addition of sodium arsenite and copper sulphate to the lick, without carbon tetrachloride drenching, would effect any reduction in the number of *Haemonchus contortus* (the stomach worm) as well as *Oesophagostomum columbianum*.

The experimental sheep comprised four trial lots:—

Lot 1 receiving carbon tetrachloride at monthly intervals, and a basal phosphatic lick;

Lot 2 receiving carbon tetrachloride at monthly intervals, with addition of sodium arsenite and copper sulphate to the basal phosphatic lick;

Lot 3 receiving medicinal lick only, with no drenching; and

Lot 4 being the control, and receiving the basal phosphatic lick only.

2. Conditions during Trial.

All the sheep were rotated in turn through four experimental paddocks, which had been left unstocked since the previous August. Stocking was light, only 30 sheep being run on 80 acres. Pasture conditions were very good at the beginning of the trial, and individual lots made gains up to 9 lb. per head in a single month. Rainfall throughout the trial was very low, and the total for the year comprised only 11.91 inches, which is very much below the average for the property. It is thought that this low rainfall was responsible for the fact that parasitic infestation was light throughout.

Body Weights.

Lot No.	Average weight at beginning of trial.	Average weight at end of trial.	Gain.
	(lb.)	(lb.)	(lb.)
1	42.6	91.0	48.4
2	36.2	92.0	55.8
3	40.8	88.0	47.2
4	40.8	92.6	51.8

Unfortunately, at the beginning of the trial, Lot 2 was non-homogeneous with the other groups, but it might be noted that it gained the most of all lots. The only other significant difference is between Lot 4 and Lot 3, the former being the control lot, and the latter receiving medicated lick only. So far as the body weights are concerned, therefore, all that can be said is that treatment certainly resulted in no gain.

Wool Weights.

All sheep were shorn at the end of the trial, in January, 1933, the average weights of wool per head for the several lots being:—

Lot 1	..	..	..	9.24 lb.
Lot 2	..	..	..	8.49 lb.
Lot 3	..	..	..	8.53 lb.
Lot 4	..	..	..	8.98 lb.

The difference between Lot 1 and Lots 2 and 3 is almost significant, but that between 1 and 4 is not. It is seen that one lot receiving carbon tetrachloride drenching cut slightly more wool than the others, while the other carbon tetrachloride lot, receiving also medicated lick, cut the least of all lots. According to the classer's estimate, the fleece in Lots 1 and 2 were of slightly better quality than those in 3 and 4, but the individual analyses of the fleece do not indicate this definitely.

Lick Consumption.

Lick consumption throughout the trial was light, and the highest was 5 gms. per sheep per day; the lowest during one or two months was a little more than 0.75 gm. per sheep per day. Consumption in Lots 2 and 3 (medicated) was not appreciably lighter.

Parasitic Infestation.

At the beginning of the trial, parasitic infestation was heavy, in four lambs of the same age killed before the trial the average degree of infestation being over 1000 *Haemonchus contortus*. Apparently, through being placed on clean paddocks which had been spelled for five months, and through the good condition of the pastures, the lambs received a good start, and at no time did the untreated lambs suffer in comparison with the treated.

So far as the efficiency of drenching is concerned, it was found in months in which no rain fell that the monthly treatment with carbon tetrachloride almost completely eliminated infestation with *H. contortus*. This was seen particularly at the January weighing, no rain having fallen for over a month.

At the end of the trial, five sheep from each group were examined post-mortem. In Lots 1 and 2, out of 10 sheep examined, only two showed any *Haemonchus* infestation, and then with only a few worms in a single sheep from each group. In Lots 3 and 4, 9 out of 10 sheep examined showed light to moderate degrees of infestation, the number of worms being estimated as from 50 to 500.

During the months in which several falls of rain occurred, it was found that even the treated groups showed a high percentage of *Haemonchus* larvae at the next monthly weighing.

So far as the *Oesophagostomum* infestation was concerned, against which the medicinal supplements were employed, infestation in all groups was light, and there was no significant difference in the numbers found in any group. This confirmed the findings in the Tasmanian trial.

3. Conclusion.

As a result of the evidence obtained in this experiment at "Meteor Downs," namely, that light to moderate degrees of infestation with *H. contortus* caused no interference with growth or wool production, a trial has been started on "Hinchinbrook" (see page 214) to investigate this point more thoroughly. The practical applications are possibly of importance, for should it be confirmed that sheep can tolerate a light to moderate infestation with worms—hitherto considered to be of some importance, depending on the degree of infestation carried—without reduction of growth or wool production, it would mean that drenching could be concentrated on eliminating heavy degrees of infestation, and safeguarding against these when climatic conditions predispose to them.

Pyrethrum.

By A. McTaggart, Ph.D.*

Evidence has recently been forthcoming that a few people in Australia are already producing pyrethrum, and that others would appreciate further information in regard to it. The article that follows may therefore be of fairly wide interest. If, however, it succeeds in drawing attention to the limited Australian market for pyrethrum it will have served one of the purposes of its publication. It can hardly be too strongly emphasized that by the planting of a few hundred acres the total Australian demand could be satisfied, and that extra plantings would mean that the very keen competition of the export trade would be encountered.--ED

1. Introduction.

In recent years, attention has been given in various countries to a study of cultural and other problems associated with pyrethrum (*Chrysanthemum cinerariaefolium*), the flowers of which, when dried and ground to a powder, form a raw material for the manufacture of one of the most effective and conveniently used insecticides, viz., the well-known fly spray. (Such sprays are made by leaching the powder from dried pyrethrum flowers with a petroleum oil fraction resembling kerosene, and adding small amounts of essential oils to scent the mixture.)

An incentive for such studies has, no doubt, been the phenomenal increase in the world production of pyrethrum, particularly in Japan. Recently, brief mention of the matter has been made in the press throughout Australia, and hence the following more detailed information may be of interest.

* Senior Research Officer, Division of Plant Industry.

2. Brief History of Culture.

Pyrethrum is believed to have originated in the Mediterranean region. It appears to have been known in Persia for its insecticidal properties for several centuries. The early 19th century saw its introduction, or re-introduction, into Europe, from Persia. Then, as now, it was the red-flowered common species (*Chrysanthemum roseum* or *C. coccineum*) that was grown in that country. During the period 1850-60, a new and more valuable species (*C. cinerariaefolium*) was produced in Dalmatia. It was white or yellow-flowered, and was destined to become the most widely cultivated type of the present day.

In 1881, Japan introduced the plant from Dalmatia. Following successful experiments near Tokyo, serious cultivation began in that country in 1886. Cultivation spread rapidly, and the year 1896 saw its introduction into Hokkaido (the northern island of Japan), where 64 per cent. of that country's production occurs to-day. Japan now claims 70 per cent. of the world's yield of flowers. Austria and Jugoslavia also produce pyrethrum in fairly large quantities. In addition France, Switzerland, Spain, North Africa and Argentina grow the plant on a limited scale for home use.

Production in Japan.—The Great War having opened the world's markets for the product to Japan, cultivation of the plant in Hokkaido, in consequence, reached significant proportions. In 1914, less than 10,000 lb. per annum were produced there, with only 2,150,000 lb. in the whole of Japan. Owing largely to the conversion of land to the cultivation of pyrethrum (the only crop which at the time gave a profitable return for farm labour) phenomenal expansion of the pyrethrum acreage in Hokkaido took place. In 1926, the peak year, nearly 26,000 acres of the crop were grown on that island, which acreage yielded over 10,000,000 lb. of dried flowers. In Japan as a whole that year some 33,728 acres produced 15,993,037 lb. This proved to be over-production, and there has since been a decrease in the area cultivated.

The approximate average annual output per acre during the period 1911 to 1928 for Japan was 500 lb., while for Hokkaido province it was 347 lb. The apparently low average yield of the latter was due largely to the fact that on that island pyrethrum is grown in very poor soils—unfit for the cultivation of other crops. Moreover, irrigation is not practised there.

Cost of production and net income in Japan.

The average cost of production of pyrethrum and the net income per acre, in Japan, are as follows:—*

Total cost of production per acre over 5 years ..	=	£35	0	0
Average cost of production per acre per annum ..	=	7	0	0
Gross income per acre over 5 years (on basis of a crop during 3rd, 4th, and 5th years, totalling 1518.3 lb. at approximately 11½d. per lb., the average price for the few years prior to 1930)	=	74	0	0
Net income per acre for the 5 year period ..	=	39	0	0
Net income per acre per annum ..	=	7	16	0
(Par value, 24.58d. per yen, was used in calculating.)				

* From an article in the *Bull. Imp. Inst.* 28 : 328, 1930

Production in Europe.—On account of its superior quality, the Dalmatian pyrethrum product has of late years resulted in an increasing demand in Great Britain, France, Italy, Germany, and the United States of America. The year 1926 proved to be a year of over-production in Europe as it was in Japan. This resulted in a subsequent reduction of acreage, with a corresponding increase in price.

3. Experiments in various Countries.

In Great Britain, co-operative experiments conducted by the Plant Pathological Laboratory of the British Ministry of Agriculture and the Insecticides and Fungicides Department of the Rothamsted Experiment Station demonstrated that pyrethrum can be grown and harvested successfully in England, that the average yield of dried flowers was of the same order as that obtained elsewhere, and that the insecticidal efficiency of the product was not less than that of imported samples. Indeed, English-grown flowers in many instances showed a higher percentage of pyrethrins* than imported flowers. Fryer, Tattersfield, and Gimingham at Rothamsted showed that the toxicities of extracts of equal weights of pyrethrum flowers at different stages of development do not differ significantly. Tattersfield later showed that the percentage of pyrethrins present in the flowers increases up to the stage at which they are fully open, which finding was also arrived at by Gnadinger and Corl in America by use of a different analytical method. The practical importance of this discovery was such that with maturity came not only an increased yield of flowers but also an appreciably greater quantity of pyrethrins per unit area. It was also demonstrated at Rothamsted that a very poor sandy soil could produce an excellent sample of flowers, and that fertilizer applications did not markedly affect the yield and toxic quality of such. Tattersfield, Hobson, and Gimingham found 0.6 to 1.2 per cent. of total pyrethrins in the flowers, made up of approximately equal quantities of Pyrethrin I. and Pyrethrin II. (determined by the acid method). Tested in alcoholic solution against *Aphis rumicis* Linne, Pyrethrin I. was found to be 10 times as toxic to these insects as Pyrethrin II.

United States of America.—According to a report on pyrethrum trade conditions published by the Japanese Commercial Museum in San Francisco, in 1926, the United States of America is unsuited to the cultivation of the plant at competitive prices. That report showed that the republic is dependent upon Japan for at least 80 per cent. of her stocks of dried flowers, and that in 1926 she imported 8,061,000 lb. from that country. According to Glassford, flowers from all sources imported into United States of America increased from 3,000,000 lb. in 1923 to 9,000,000 lb. in 1929.

McDonnell, Abbott, Davidson, Keenan, and Nelson of the Bureau of Plant Industry, United States of America Department of Agriculture, showed that neither the commercial grade nor the locality where grown can be accepted as giving an accurate criterion of the effectiveness of the pyrethrum product against insects. They concluded that samples of the same grade may differ in efficiency more so than samples of different commercial grades, such differences arising from (i) variations in active constituents due to differences in variety, climate and soil; and (ii) variations in conditions associated with harvesting, and with methods of curing, shipping, and storing of flowers.

* The toxic principles of the pyrethrum flower (see under "Switzerland," p. 207).

The experiments of Gnadinger and Corl, referred to above, showed that pyrethrum flowers which have fully opened contain 18 to 61 per cent. more pyrethrin than the closed flowers, which for many years were thought, erroneously, to be superior. These workers also found 0.4 to 1.21 per cent. total pyrethrins in the samples of flowers and powders tested.

Glassford, writing on the economics of pyrethrum, referred to recent investigations having shown that, by use of proper materials to activate the pyrethrum powder, a spray of remarkably increased toxicity is obtained, the cost of spraying being as a result correspondingly reduced. This advantage, together with that associated with the possibility of doubling the yield of pyrethrins by allowing the crop to mature more fully before harvesting, might well result in the production of a finished pyrethrum spray reduced in cost by half the current price per gallon, thereby making it comparable in cost with lead arsenate spray. He also referred to experiments with pyrethrum dusts, pointing out that extract of pyrethrum when carried on the surface of dust particles is definitely increased in efficiency, the cost of dusting being thereby correspondingly reduced. Used in this way, the pyrethrins were efficient for some purposes at a dilution of 1 to 133,000.

According to the same writer, the average consular invoice values in the United States of America decreased from 47 cents (1s. 11½d.) a lb. in 1923 to 18 cents (9d.) a lb. in 1929. (Recent wholesale prices for dried pyrethrum flowers in the United States of America have been quoted as low as 16 cents (8d.) per lb.)

Switzerland.—Two Swiss chemists, Staudinger and Ruzicka, first isolated, determined the chemical structure of, and named, two toxic constituents in pyrethrum flowers—Pyrethrin I. and Pyrethrin II. They found them present to the extent of only from 0.2 per cent. to 0.3 per cent., and consisting of approximately 40 per cent. of Pyrethrin I. and 60 per cent. of Pyrethrin II. Staudinger and Harder later stated that the content of total pyrethrins may in favorable cases amount to 0.6 per cent. They also found no difference between open, half-open, and closed flowers in percentage of toxic constituents. (Later work by Tattersfield and by Gnadinger and Corl, above referred to, showed that the percentage of total pyrethrins increases with the maturity of the flowers.) A method for the chemical assay of pyrethrum preliminary to the development by selection and propagation of a strain of *Chrysanthemum cinerariaefolium* of higher toxic value than that now grown was also developed by these Swiss scientists.

Other Countries.—Pyrethrum was grown successfully in Kenya, and the dried flowers were tested in England. The report showed that the flowers contained a satisfactory content of Pyrethrin I., the analyses revealing 0.56 per cent., 0.28 per cent., and 0.39 per cent. for "full bloom," "half closed" and "buds" samples, respectively. The first and last samples were considered higher in Pyrethrin I. content than Dalmatian flowers of average quality, and all three samples to be worth a little less than the current (April, 1930) price of "open flowers" from Dalmatia (a fraction over 10d. per lb.).

Pyrethrum flowers of good quality have been grown in the Island of Cyprus, while tests carried out in Uganda, Tanganyika, and Trinidad showed that the pyrethrum plant grows there, but that it will not

produce flowers. At high elevations in tropical countries, however, flowers may be produced, as was shown by the tests conducted in Kenya.

4. Experiments in Australia.

According to Baron von Mueller, *Chrysanthemum cinerariaefolium* was grown on a large scale on the Lower Latrobe River, Victoria, some time prior to 1895. The powder produced from the flowers was described as being "very powerful."

Chrysanthemum roseum (Persian species) has lately been grown commercially at Milperra, New South Wales, and sprays are being made in Sydney from the flowers grown there.

At Ormond, Victoria, both *Chrysanthemum cinerariaefolium* and *C. roseum* have been grown on a commercial scale for the past three years.

In 1931, the Plant Introduction Section of the Division of Plant Industry, incidentally to its main work of introducing and testing varieties of grasses likely to be of value in Australia, introduced a small amount of seed of four strains of *Chrysanthemum cinerariaefolium*:—

C.P.I. No.	Strain.	From - -
2273	Swiss	Viticultural Station, Lausanne, Switzerland, received through C. T. Gimingham, Brit. Ministry of Agric., Harpenden, Eng.
2274	Japanese Commercial ..	Japan, received through C. T. Gimingham, Harpenden, Eng.
2288	Japanese	Yokohama Nursery Co., Ltd., Yokohama, Japan
2289	Japanese	Japan, through Office of Drugs and Related Plants, U.S. Dept. of Agric., Washington

Seedlings were raised in flats (seed boxes) and transplanted into the field in October, 1931, at Black Mountain, Canberra. The plants were set out in rows 18 inches apart and 12 inches apart within the row. They were periodically watered during the dry period of the year, and intercultivated only when necessary to keep down weeds. The soil was a rather poor clay loam, on a gentle slope. (Pyrethrum does best in poor soils.) The plants reached maturity and produced flowers abundantly in the second season, giving yields of heads (dried, disintegrated, and pulverized) at the following rates:—

C.P.I. No.	Strain.	Yield per Acre (lb.).
2273	Swiss	1,153·2
2274	Japanese Commercial ..	1,174·4
2288	Japanese	1,256·0
2289	Japanese	1,177·3
	Average	1,190·2

Preliminary tests with the powders produced, which were carried out pending the making of provision for more comprehensive tests, showed that each was effective in destroying different insects.

The following shows the estimated cost of production per acre during the first two seasons of the above-mentioned yield (first) of flowers from the average of the four strains, based on the experience at Canberra:—

(1) Preparing flats, seeding and growing therein, and transplanting individual plants into the field (2 men—6 days at £4 12s. 0d. per week of 5 days)	£11	0	0
(2) Intercultivating and watering (1 man—3 weeks of 5 days at £4 12s. 0d. per week)	..	13	16 0
(3) Harvesting—cutting, drying, disintegrating and pulverizing heads (2 men—3 days at £4 12s. 0d. per week of 5 days)	.. ..	5	10 0
(4) Water used, during two seasons (the period necessary at Canberra to produce mature plants, also flowers)	.. ..	7	14 0
		<hr/>	<hr/>
		£38	0 0
		<hr/>	<hr/>
Estimated average cost per acre per annum during first two years		£19	0 0
		<hr/>	<hr/>

Estimation of the average cost of production per acre per annum, with the corresponding net return per acre per annum, over a period of five years (the normal period of establishment plus productiveness), as was done from Japanese pyrethrum statistics, must necessarily await the obtaining of further results in later years.

It should be specially noted that in Europe and Japan a crop is not harvested until the third year, whereas in Australia, judging by the results obtained to date at Canberra, a satisfactory yield of flowers can be secured in the second season of growth.

5. Conclusions.

Tests conducted in Australia to date, at Canberra or elsewhere, are insufficient in scale, distribution, and duration definitely to decide the point as to whether or not pyrethrum can be grown profitably in Australia in competition with overseas production and the importation of dried flowers for processing here.

By the use of careful intensive methods—including the periodic supplying of the growing plants with adequate, though not excessive, quantities of water, it may be possible for the Commonwealth to supply her own requirements economically. It should be emphasized, however, that these requirements are small, for from figures supplied by the Commonwealth Statistician in the Overseas Trade Bulletin, No. 27, it appears that Australia imported annually during the period 1927-32 an average of 2016.4 cwt. of dried pyrethrum flowers of an average value of £12,940, the value per pound being slightly over 1s. 1d.

In other words, the planting of a few hundred acres would be sufficient to satisfy the whole of the Australian demand. The planting of any greater acreage would inevitably involve Australia entering into an export trade, and here she would have to overcome satisfactorily the effects of such factors as (i) heavy, well-organized, experienced, and economical foreign production; (ii) a rather low prevailing price for the overseas product, in consequence of a recent tendency to over-production and of depressed financial conditions; and (iii) a marked depreciation in the values of the currencies of pyrethrum-producing countries, notably Japan.

6. Literature consulted.

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2. "Pyrethrum as an insecticide and its cultivation in England," by J. C. F. Fryer and C. T. Gimingham, Plant Pathological Laboratory, British Ministry of Agriculture.—*Nature*, 127: 593, 1931.
3. Report for 1931 of the Rothamsted Experimental Station, Harpenden, England: pages 46, 86, and 87, giving condensed account of miscellaneous investigations with pyrethrum by F. Tattersfield, J. T. Martin and R. P. Hobson.
4. "The economics of pyrethrum," by John Glassford, Chief Chemist, McCormick & Co., Inc., Baltimore, Md., U.S.A.—*Jour. of Economic Entomology*, 23: 874-877, 1930.
5. "Relative insecticidal value of commercial grades of pyrethrum," by C. C. McDonnell, W. S. Abbott, W. M. Davidson, G. L. Keenan, and O. A. Nelson.—United States Department of Agriculture, Technical Bulletin No. 198 (July, 1930).
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7. Experiments with pyrethrum in Cyprus—brief reference in *Bull. Imp. Inst.*, 28: 427-429, 1930.
8. "Select Extra-tropical Plants," by Baron Ferd von Mueller, Government Botanist for Victoria (1895), p. 120.
9. Commonwealth Overseas Trade Bulletin No. 27 (issued annually by Commonwealth Bureau of Census and Statistics).

The Occurrence of Pilchard Eggs and Young Stages of the Pilchard in the Coastal Waters off New South Wales.

*By William J. Dakin, D.Sc., F.Z.S.**

During the past three years, certain marine biological investigations have been carried out a few miles off the coast of New South Wales, eastward of Port Jackson. This work, undertaken in conjunction with the marine laboratory of the Sydney University, has been aided by the Trustees of the Science and Industry Endowment Fund, and for that reason a rather interesting discovery, which has important commercial bearings, might be of interest to readers of this Journal.

It is, perhaps, not generally known that the eggs of most marine fishes of commercial importance (apart from the somewhat distinct groups of sharks and rays) are rather small, are produced in enormous numbers in the female fish, and are set free and fertilized externally in the sea water, where they float during their subsequent development. It is important to note this last fact. During the time that elapses before hatching, the tiny delicate eggs float about, and are carried hither and thither by sea currents with the varied assortment of minute plants and animals constituting the assemblage known as "plankton."

It is probable that the high rate of egg production in the individual fish is directly correlated with the great risks attending this mode of reproduction and the fact that a high death rate may occur during the early stages after hatching.

It is possible to determine the breeding place and date of breeding season of a marine fish by the capture of the fish eggs in plankton nets. It is also possible, in some partially enclosed waters, to form a quantitative idea of the total fish population by this means. It is essential, however, that the fish eggs can be recognized as belonging to this or that species of fish. In the North Sea, for example, as a result of years of study and exploration, all the different kinds of eggs, not only of the fishes commercially important as food, but of many other species, have been described and illustrated. Accordingly, they can be recognized under the microscope. This also applies to the young stages. However, we know practically nothing about the eggs of the fishes of the Australian coast, and the matter is much more complex by reason of the greater number of fish species present.

There are two methods of tackling the problem. One is to press eggs out of a captured mature female fish, fertilize them in an aquarium tank with sperm from a male fish, and then to endeavour to rear the eggs as far as possible. In this way, of course, the species of fish is obviously known from the beginning. It is not, however, a plan which can always be carried out. The other method is to catch eggs and larvae with special plankton nets, and to go on doing this until gradually, like a jig-saw puzzle, a series can be put together, leading from the egg through various sized stages from the just-hatched larva

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until one is obtained which is big enough, or characteristic enough, to be recognizable as this or that species of fish. That, of course, supplies the clue for all the earlier stages and the egg itself. Naturally, this line of investigation requires time and patience.

During the last three years, my colleague, Mr. A. Colefax, and myself have examined hundreds of plankton catches from the New South Wales coastal waters, and each year, during the period from May to September, we have found a certain kind of egg which we thought might reasonably be regarded as belonging to some fish of the herring tribe. But no larvae later than the just-hatched stages were discovered.

This year, however, a special effort has been conducted with a large net, and every week after the eggs first appeared a search was made at sea for young stages. Over a period of six weeks, we had considerable success; each successive week bringing in a few larger individuals, until at last a stage was reached which left no doubt in our minds that the eggs were those of the Australian pilchard (*Sardinia neopilchardus*).

It is possible, therefore, to state quite definitely, not only that the pilchard is breeding off Sydney during the months from May to September, but that the numbers must be very great to give the density of eggs in the water sampled by our nets.

It is well known that the pilchard is one of the most valuable fishes to the United States of America, both for canning purposes and for oil and fish meal manufacture. The Australian pilchard is very like the European pilchard, and should can well. There should also be a demand for its oil. At the present time, however, no pilchard fishing takes place off the coast of New South Wales or Victoria. Even the gear necessary for what might be a considerable industry is lacking.

The results of this plankton investigation should supply some useful clues to the possible commercial exploitation of this fish species.

NOTES.

Tick and Blowfly Problems.—Suggested Use of the Cattle Egret Bird (*Babulcus Coromandus*).

Some six months or so ago a little attention was given throughout the press of Australia to suggestions that had been put forward that perhaps the cattle egret bird (*Babulcus Coromandus*) might be of some value, if imported into Australia, for it might serve as a means of controlling the cattle tick and perhaps the blowfly and buffalo-fly pests. Although the consensus of opinion of local authorities which the Council consulted was adverse in regard to the possibilities of the birds, nevertheless it seemed as well to obtain practical information from countries where the egret is plentiful. Accordingly, the advice of the Imperial Council of Agricultural Research, Simla, India, was sought. Recently, a helpful reply from that Council has been received. It includes the following passages:—

“ . . . I am directed to say that inquiries made of the authorities mentioned therein have not elicited any information of value other than the note on Egrets published in the Memoirs of the Department of Agriculture in India Entomological Series, Vol. III. Cattle egrets (*Babulcus Coromandus*) are quite common in the rice areas of Southern India, but not so common in the drier areas of the north. They, no doubt, consume large numbers of ticks, but, as a means of keeping this pest under control, they are quite ineffective. In certain most densely-wooded parts of Southern India, where conditions are not so favorable for the egret, cattle are liable to be infested with ticks in extremely large numbers, and it is possible that the lack of egrets may, to some extent, be responsible for this. On the other hand, in Egypt and the Sudan, where similar tick birds are very common and must consume large numbers, ticks are a very common pest. Nowhere in fact, according to our observations, have these birds, in any way, obviated the necessity for artificial methods of control, such as dipping, if ticks are ever to be brought under satisfactory control, and it seems very unlikely that the egret would have any marked effect on tick or fly infestation in Australia, particularly in the drier areas.

“I am to add that no opinion can be expressed as to the likelihood of the egrets changing their feeding habits in a new environment.”

Requests for Publications by Predecessors of the Council.

The response to the request in the previous issue for copies of the publications of the two predecessors of the Council, namely, the Advisory Council of Science and Industry and the Institute of Science and Industry, has already been quite helpful, and the Council is duly appreciative. However, use could be made of additional copies for which the present owners have no further use. The numbers in question are Bulletins Nos. 1 to 9 inclusive, 14, 18, 20, 21, and 26.

The F. D. McMaster Animal Health Laboratory—Field Area at “Hinchinbrook.”

A brief description of the F. D. McMaster Animal Health Laboratory, and of Mr. F. D. McMaster's gift of £20,000 to cover the cost of erection and equipment of the laboratory, has been given in previous issues (Vol. 2, p. 193, and Vol. 4, p. 201). Mr. McMaster has recently added to his gift by assisting in providing the laboratory with a small area on a property he is renting at “Hinchinbrook,” near Sydney.

Some time after the erection of the main laboratory, the need was felt for accommodating a larger number of animals than was possible at the laboratory itself. It also became evident that facilities for keeping sheep under natural grazing conditions would be helpful.

Accordingly, numerous properties were inspected in the County of Cumberland, and finally one which appeared suitable in every way was selected, this being “Hinchinbrook,” comprising 2,000 acres, situated about 22 miles from the University, and lying to the south, on the Old Cowpasture-road, not very far from Liverpool. Difficulty, however, was experienced in leasing that portion which was suitable, and for which the necessary finance could be arranged. On learning of this difficulty, Mr. McMaster offered to inspect the property with the intention of leasing the whole of it, if he approved of it as a pastoral property, and then making available to the Council such portion as the latter required. This was subsequently arranged, Mr. McMaster taking over the leasehold of the property for three years from October, 1932. He most considerably allowed the Council to select the portion of the property most suitable for its purpose. Accordingly, an area of 300 acres was handed over and subsequently divided into small experimental paddocks. Of these there are six experimental paddocks of 15 acres each, two of 30 acres each, and two more extensive paddocks are also available for running larger groups of sheep. The section of the property selected for the Council's work is bounded by the Metropolitan Water Board's race, from which water is now siphoned to troughing in each paddock.

The necessary fencing, provision of water troughing and other material, &c., have been completed, and experimental work has been in progress for the last six months. Over 400 sheep, of which number incidentally more than 300 have been donated by pastoralists, including Mr. McMaster, Mr. E. D. Ogilvie, Mr. J. Busby, and the Camden Park Estate, are being depastured on the experimental paddocks. A two-roomed field laboratory has been erected in close proximity to the experimental paddocks, and in this erection the necessary equipment for carrying out routine pathological and parasitological examinations is installed.

Under the arrangement with Mr. McMaster, half the cost of the wages of a resident overseer are borne by him and half by the Council. The latter also meets a proportionate cost of the rent.

Experiments now in progress at “Hinchinbrook” include the following:—

(i) The determination of the effects of light, medium, and heavy parasitological infestation on young lambs, in relation to wool growth and mutton production. Indications have been obtained in other experimental work that, unless parasitic infestation reaches a fairly high degree of severity, no appreciable deleterious effects on the sheep are experienced.

(ii) In connexion with investigations on caseous lymphadenitis, 100 ewes suffering from the disease will lamb on "Hinchinbrook," and, with their progeny, will be depastured there for two years. The lambs will not enter the shearing-shed, and will be tailed, marked, and shorn at grass, so that the influence of indirect infection through contamination of shearing-sheds as against infection through other agencies will be checked and determined.

(iii) One hundred Merino ewes are being maintained at "Hinchinbrook," so that the main laboratory will have a supply of parasite-free lambs at all times. (The ewes, immediately on lambing, are brought to the laboratory, and maintained with their lambs under conditions which eliminate the possibility of the latter becoming infested with parasites.)

(iv) A small programme of cross-breeding experiments is in progress to determine the manner of inheritance of wool and mutton characters in sheep. For this purpose, 100 Merino ewes of the original Camden Park stock have been crossed with Border-Leicester rams, the latter being generously given to the laboratory by Mr. L. A. Hamilton, of Rylstone. The progeny will be classed, and a detailed analysis made of their wool and mutton characters, and the ewe progeny will be subsequently back-crossed to the Border-Leicester sires.

Bunchy-Top of Bananas.

The recent recrudescence of outbreaks of bunchy-top of bananas in various Australian banana-growing districts may serve as an occasion on which to correct the erroneous impression, extant in some quarters, that the scientific investigations on which the present system of control of bunchy-top is based were the sole responsibility of the Council for Scientific and Industrial Research and of its predecessor, the Institute of Science and Industry.

Actually, those investigations were carried out at the joint expense of the Governments of the Commonwealth, of New South Wales, and of Queensland, each party contributing on a 1:1:1 basis. The work itself was controlled by a body known as the Bunchy-top Control Board, which consisted of representatives of the contributing Governments. The main result was to demonstrate that bunchy-top is a virus disease carried by an insect vector—an aphid.

The scientific personnel available to the above Board included Professor Goddard, of the University of Queensland, as supervisor; Mr. C. J. P. Magee, B.Sc.Agr., for pathological problems; and Mr. H. Collard for horticultural work. At the time of the initiation of the investigations, Mr. Magee was an officer of the New South Wales Department of Agriculture, but his services were made available to the Board by that Department.

The report of the investigations was published under Mr. Magee's name as Bulletin 30 of the Council for Scientific and Industrial Research. Mr. Magee himself, however, has long since returned to the service of the New South Wales Department of Agriculture.

Investigations on Apple Thrips.

The occurrence of widespread thrips infestations over the southern areas of Australia has been recorded at intervals during the past 25 years; the most recent infestation occurred in the spring of 1931.

These infestations are associated with a marked reduction in the apple crop in the years concerned and with State-wide fluctuations in yields from orchards.

During 1930-31 Mr. J. W. Evans, an officer of the Division of Economic Entomology of the Council, began to investigate the thrips problem. (See this *Journal*, November, 1930, p. 239.) A large part of this work was carried out at the Waite Institute, and an account of Mr. Evans's observations was published in 1932 (Pamphlet No. 30, Council for Scientific and Industrial Research).

The Thrips Investigation League, which was formed in 1932 by growers, merchants, and others interested in the fruit industry, offered to contribute £1,200 a year for three years towards the cost of a more extensive investigation of the problem. Therefore, the research programme has been considerably extended as a co-operative enterprise between the Council, the Waite Agricultural Research Institute of the University of Adelaide, certain of the State Departments of Agriculture, and the Thrips Investigation League.

The programme consists of an investigation of *Thrips imaginis* and associated species of blossom and flower thrips, particularly with reference to their economic importance in relation to the apple-growing industry. The investigation is under the direction of Dr. J. Davidson, head of the Department of Entomology at the Waite Institute.

Certain aspects of the work are being developed at the Waite Institute, and Mr. Evans has been attached to the Entomology Department in this connexion. Mr. W. H. Wheeler has been appointed as chemist to assist with the insecticides aspect of the investigations.

Other aspects of the work are being developed in Victoria. Mr. H. G. Andrewartha has been appointed as entomologist in this connexion, and he is assisted by Miss H. V. Steele, who has been working on thrips during the past year. Through the courtesy of the University of Melbourne, this unit will be accommodated at the School of Agriculture of the University.

The Departments of Agriculture of South Australia and Victoria are co-operating in the field observations and experiments, and various growers in these States have offered certain facilities in these matters.

When suitable progress has been made in the investigation, it is hoped to extend the work to Western Australia. It is desirable to concentrate on the work in South Australia and Victoria for the present, and the results obtained will have a general application to other States.

It is proposed to publish certain results from time to time, which will serve to indicate the progress of the investigation. These results and the conclusions to be drawn from them, together with recommendations regarding control measures, will be published in the Bulletin series of the Council on the completion of the investigation.

Low Temperature Breakdown in Tasmanian Apples.

(Contributed by W. M. Carne, Division of Plant Industry.)

The object of this note is to record the common and serious recurrence of low temperature breakdown in Tasmanian apples, a disorder not previously recorded from Australia (including Tasmania).

On transferring to Tasmania in July, 1932, the writer made a survey of the wastage occurring in apples in Southern Tasmanian cool stores. By October, wastage was found to be serious and widespread, though fruit from certain orchards was much more affected than from others. Through the inspectors of the Department of Agriculture, it was ascertained that similar wastage was occurring in cool stores in the northern part of the State not visited by the writer. From the same source it was ascertained that similar wastage occurred annually, but varied in different years, 1929 being the previous bad year. The varieties affected were mainly Scarlets, Sturmer, and French Crab, the former from about August, and the two latter from about October.

On personal experience of low temperature breakdown in Bramley's Seedling, seen in England in 1931, and from published data, the principal cause of wastage in Tasmania was tentatively diagnosed as being this disorder. Low-temperature breakdown is known to develop in certain varieties in Great Britain, New Zealand, and the United States of America when stored at temperatures below 38-40 deg. F. Apples vary in susceptibility according to soil and climatic conditions, size of fruit, &c., and when very susceptible are liable to break down at even 38 deg.

As this disorder had not been previously recognized in Australia, steps were taken in 1933 to confirm the diagnosis. To this end, arrangements were made with the Department of Agriculture and the Huonville Co-operative Cool Store to provide suitable accommodation. The Department erected a small chamber in the cool store, the co-operative society providing the refrigeration. Fruit was obtained from several sources, and particularly from those orchards which had a poor reputation for the storage properties of their fruit. Certain varieties were also obtained from orchards giving fruit of good storage reputation. The following varieties were stored:—Cox's Orange Pippin, Jonathan, Cleopatra, French Crab, Sturmer, Scarlet, Delicious, and Democrat. In each instance, the fruit was divided between two chambers as under:—

Chamber.					Commercial		Special.	
Cooling system	..	..	..	..	Cold air	..	Overhead grids	
Temperature at 6 feet from floor	..	..	..	..	31°-34°	..	38°-40°	
Humidity	..	..	..	..	92-99 %	..	90-98 %	

The storage tests will be completed about November. So far, it has been shown that low temperature is definitely associated with breakdown in Cox's Orange Pippin and Jonathan. In the former, the symptoms were typical of those recorded in this variety by the Cambridge Low

Temperature Research Station in England and by the Cawthron Institute in New Zealand. The incidence of breakdown after less than ten weeks' cool storage varied from about double to over 30 times as much at the lower as at the higher temperature, according to the tree from which the fruit was taken. The breakdown in this variety is of the soggy type, and agrees with that recorded for Grimes and Wealthy apples in Iowa, U.S.A., by Plagge and Maney (Iowa Agric. Expt. Sta., Res. Bull. 115, 1928). In Jonathan, breakdown developed in less than ten weeks' cool storage, as in Cox's Orange Pippin, but was of a mealy type. In the only line (two pickings) of this variety used, the wastage at the lower temperature was approximately twice that at the higher.

The following types of breakdown associated with storage at low temperatures have been noted to date:—

Soggy Type.—Sturmer and French Crab. Severe in 1932 in all cool stores in State. Cox's Orange Pippin in 1933.

Mealy Type.—Scarlets in 1932. Jonathan in 1933. This form in Jonathan and Scarlets has caused serious complaints on the Sydney markets in 1933. There are indications that even ordinary storage on the orchards in Tasmania is at too low a temperature for susceptible fruit.

Core Flush.—Scarlet 1932.

Standard Methods for the Chemical Analysis of Butter.

Some time ago, the Dairy Research Committee of the Empire Marketing Board appointed a sub-committee to prepare suggested uniform methods for the chemical analysis of, and reports on, dairy products. It was felt by the Committee that a useful purpose would be served if such methods were prepared by a central body and circulated to dairy research workers throughout the Empire in the hope that, if they find general acceptance, they might be adopted as standard methods. By such action, co-operative work between dairy experts in different parts of the Empire might be made of greater scientific value, since greater uniformity of results might be expected to follow the use of a common technique.

The sub-committee has recently completed the preparation of standard methods for the chemical analysis of, and reports on, butter. These have been approved by the Dairy Research Committee, and copies of them have been received from the Secretary of the Empire Marketing Board, with a request that they be circulated for the information of dairy research workers in Australia. The standard methods relate to—(a) sampling, (b) moisture, (c) curd and salt, (d) fat, (e) acidity, (f) casein, and (g) lactose.

Copies of the standard methods have been sent to the Commonwealth Department of Commerce, the State Departments of Agriculture, and the Departments of Agriculture at the four Universities at which Chairs of Agriculture have been established (Sydney, Melbourne, Queensland, and Western Australia). Copies of them can also be obtained by dairy research workers in Australia on application to the Secretary, Council for Scientific and Industrial Research.

The Use of Electrical Moisture Meters for Determining the Moisture Contents of Veneer and Plywood Respectively—Preliminary Investigations.

(Contributed by W. L. Greenhill, B.E., Division of Forest Products.)

The Division of Forest Products has done much to popularize the use of the Blinker electrical moisture meter for determining the moisture content of timber. This instrument and its use are described fully in the Division's Trade Circular No. 9. It depends for its operation on the variation of the electrical resistance of timber with moisture content. The type of electrodes usually employed consists of two steel blades attached to the head of a special hammer, the blades being driven into the piece of timber which is to be tested. The use of these blades becomes impracticable when the specimen to be tested is less than about $\frac{1}{4}$ inch in thickness, as the timber splits and satisfactory contacts between the timber and the blades cannot be obtained. Besides this, the marks made by the blades would be very undesirable in thin veneer material.

With the object of investigating the possibility of extending the use of electrical moisture meters to include the testing of veneer stock, preliminary investigations were carried out on the use of plate electrodes with the veneer clamped between, and on the measurement of the electrical resistance across the timber in that way. This method can be successful only when testing very thin stock in which appreciable moisture gradients are absent. Measurements were made to investigate the effect on the electrical resistance of variations of the pressure between electrodes, area of electrodes, thickness of timber, and species of timber tested.

The results indicate that:—

- (i) Provided the pressure between the electrodes is above a certain minimum, the resistance is practically independent of the pressure. The value of this minimum resistance varies from sample to sample, and apparently is that necessary to flatten out the veneer and secure proper contact.
- (ii) As would normally be expected, the resistance is proportional to the thickness of the veneer and inversely proportional to the area of the electrodes.
- (iii) The resistance varies with the species of timber.
- (iv) With veneer sheets of the usual range of thicknesses, the resistance between suitably proportioned plate electrodes is less than that between the blades of the ordinary Blinker hammer, the species and moisture content being the same in the two cases. It should be possible to extend the lower limit of the ordinary Blinker range of readings of moisture contents by 1 or 2 per cent.
- (v) The electrodes must be placed a reasonable distance in from the edge of the veneer sheet being tested, and checks in the sheet are likely to render the readings inaccurate.

There appear to be no theoretical difficulties in the way of using the surface type of electrodes and calibrating an ordinary Blinker to give the moisture content of veneer sheets of any one thickness and species, from about 6 per cent. to about 20 per cent. The change of resistance

with moisture content is so rapid at the lower end of this range, that if an instrument were calibrated on, say, 0.05 inches thick veneer, the effect of variations in the thickness of the veneer from 0.025 inches to 0.075 inches would be completely overshadowed. Thus, variations in thickness of veneers of this order would give rise to errors of not more than 0.5 per cent. in the moisture content determination, if the moisture content itself were 9 per cent. or less.

A design of suitable equipment for carrying the electrodes for testing veneer sheets of commercial size has been developed. In this, the arms carrying the two electrodes extend out for 18 inches to 2 feet, so that tests can be made near the centre of ordinary sized veneer sheets. After the sheet is inserted between the electrodes, these are forced together by means of a spring, and the moisture content reading is made. A small hand lever is used for removing the pressure of the spring.

Tests have also been carried out to investigate the possibility of determining the moisture content of plywood, as distinct from plywood stock, by means of a Blinker, but the results are not promising. Casein glue is most commonly used in plywood construction, and, apparently owing to the varying constituents and amount of glue used, reliable moisture content indications cannot be obtained by electrical resistance methods. The resistance of the glued wood is considerably less than that of the wood alone, and the results obtained may give the moisture content from 2 to at least 7 per cent. above the actual value. No tests have been made with animal or vegetable glue, but it is probable that glues of either of these types would not affect the electrical resistance of the wood to the same extent as casein glue.

“Industrial Research and the Nation’s Balance-sheet”—Excerpts from an Address by Sir Frank E. Smith, K.C.B., D.Sc., Sec.R.S., &c.

A few printed copies of the 8th Annual Norman Lockyer Lecture, which the Secretary of the British Department of Scientific and Industrial Research, Sir Frank E. Smith, delivered to The British Science Guild in November last, have recently become available in Australia. In emphasizing the importance of research, the speaker mentioned a number of interesting points. Some of these are quite familiar, but many others have not been the subject of much public attention in this country. A few extracts are given below:—

“The nation’s most valuable plant is in the form of buildings. It is difficult to give a precise figure for the value of buildings in this country, but as the rateable value was about 250 million pounds in 1931, a reasonable estimate of value is 4,500 million pounds. There is no doubt that science can help more in planning our buildings, and it can show the builder how to choose his materials and to build better than he does at present. The costs for wear and tear per annum cannot be less than 50 million pounds, and the obsolescence charges are enormous. Research can help reduce them and make our greatest material asset much more valuable and less costly to maintain.”

"It is true that years ago we were prosperous without organized industrial research, but it is equally true that to-day we shall fail without it."

"Research has not only improved old products and replaced old types by new and more efficient ones, it has also produced new industries. The industries associated with artificial silk, synthetic nitrates, the motor car, wireless, the cinema, and the aeroplane were unknown 50 years ago. To-day they employ many millions of workers."

"The electrical industry is older than that of the motor car. Its progress has been very rapid, and it is certain that its advance will continue. Yet we cannot see the entity which we pay for to light our homes and use for many other purposes. Why is it that progress has been so rapid and the future is so assured? I believe it to be due to the absolute necessity for those who control the technical side of the electrical industry to be men of the highest intelligence. They know that their industry was born of science, lives with science, and without science would perish. Although the entity with which they deal cannot be seen, I believe more knowledge is available of the nature of this invisible entity than is available of the nature of many of the material things seen, handled, and sold in other industries. For example, coal. If only a big research effort to determine the nature of coal had been made 50 years ago the industry would not have been in the troublous straits it is in to-day."

"Most people admit that it is good for the motor car to become better and its tires to be cheaper and have a longer life. It is also well for electrical supplies to become more general, more efficient, and less costly. It is even good for simple things like our pocket knives to be improved by research and become better and cheaper. But there are still many who believe that in the mundane things of life such as coal, cast iron, bricks, and blankets, finality has been reached, or nearly so. However, a survey of what has been done and of the knowledge available and not used makes it practically certain that there is no product of any kind which cannot be improved in quality and produced more cheaply by properly conducted research. There is no limit to knowledge, and there is no limit to technical progress. If a country had to choose between new knowledge and gold with which to fill its vaults, the wise choice would undoubtedly be new knowledge, for with it the gold can be obtained, whereas without it the gold will be lost. I believe it to be essential for our industries to avail themselves of existing knowledge and to conduct research on an adequate scale to acquire new knowledge."

"It is impossible to enumerate here the many developments due to these laboratories. They comprise apparently small things, such as a grease having negligible vapour pressure in a vacuum, to bigger things like synthetic manures, non-creasing cotton fabrics, manganese steel, and silicon steel. The latter alloy alone is estimated to have saved the world over £50,000,000 by reducing the energy losses in electrical transformers."

"Consider, for example, the photo-electric cell, which twenty years ago was a mere toy of the laboratory. To-day it is a vital link in the talking pictures; it is used as a burglar alarm; it operates in large stores to switch lights on or off with variation in daylight illumination; it groups electric lamps according to their candle-power; it arranges cigarettes in rows with the imprinted name uppermost; it selects cigars by the colour of the outside leaf; it controls the magnitude of electric currents, and it is used in television. What a change in the toy of twenty years ago!"

"It is a striking fact that to produce the same useful power seven times as much steam was required in 1888 as in 1930, and over 30 per cent. more in 1918 than in 1930. Finality has not yet been reached. At the time of his death Sir Charles Parsons was engaged in still further improving the efficiency of the steam turbine."

"In this short address I have attempted to press the claims of research not only in our industries, but also in the technical affairs of the nation. Science is but attempting to use the materials of the earth to the best advantage; Emerson's statement that 'Steam is no stronger now than it was a hundred years ago, but it is put to better use' is but an expression of what science is doing, putting to better use all the materials of the world around us. Progress in science is progress in civilization, but progress in control of production, in freedom of currencies, and like matters, is also essential if the world is to reap the optimum benefit."

Recent Publications of the Council.

Since the last issue of this Journal the following Bulletins and Pamphlets of the Council have been published:—

Bulletin No. 75.—*Nigrospora Musae* n. sp. and its Connection with "Squirter" Disease in Bananas," by Associate-Professor Ethel I. McLennan, D.Sc., Botany Department, University of Melbourne, and Shirley Hoëtte, M.Sc., Botany Department, University of Melbourne.

The investigations discussed in this Bulletin were carried out by the Botany Department of the University of Melbourne quite independently of the Council, and the latter is indebted to the Department and to the investigators concerned for the work done and for their kind acquiescence in the suggestion that their results might be published as one of the Council's Bulletins. The results of the work go to show that "squirter" in bananas is due to a fungus. The writers have isolated the fungus, and identified it as a new species of *Nigrospora*, to which they have given the name *N. Musae*. The seasonal nature of the disease has been associated with the temperature range of the fungus. It is during the winter and early spring that plantation and transport temperatures are favorable to the growth of the causal organism and render infection in the field and subsequent growth of the pathogen during rail transport both possible and probable. The localization of "squirter" to fruit ripened in the southern markets has

been correlated with the method of packing fruit in "singles," a method until recently not adopted in Brisbane, where "squinter" was formerly practically unknown. Work on further aspects of the problem is in progress.

Pamphlet No. 38.—"The Occurrence of *Anaplasma marginale* Theiler, 1910, in Northern Queensland," by J. Legg, D.V.Sc.

The work discussed in this Pamphlet forms a part of a programme of investigation which is being carried out at Townsville, Queensland, with the co-operation of the Empire Marketing Board, the Queensland Department of Agriculture and Stock, cattle-owners of Queensland, and the Queensland Council of Agriculture. It represents a preliminary survey of the piroplasmic diseases affecting bovines in Australia. The report shows that, in addition to the well-known *Piroplasma bigeminum*, at least three other types of parasites affecting the red blood corpuscles of bovines, and resulting in "redwater," occur in Australia, namely, *Theileria mutans*, *Anaplasma marginale*, and a form of *Babesiella*. A considerable amount of attention is given to *Anaplasma marginale*, which leads to serious forms of the redwater disease. The previously unsuspected existence of *A. marginale* is no doubt the explanation of the rather numerous unsatisfactory results that have followed practical operations of immunization against redwater in the past.

Pamphlet No. 39.—"The Grasslands of Australia and Some of Their Problems. A Report upon the Dairy Pastures," by William Davies, M.Sc., Empire Grassland Investigator, Welsh Plant Breeding Station, University College of Wales, Aberystwyth." This publication consists of a report which Mr. Davies made to the Australian Dairy Council subsequent to the twelve months or so which he recently spent in Australia, the visit itself being financed by the Empire Marketing Board and the Australian Dairy Council. The different varieties of Australian pasture grasses of importance are discussed at some length, and, in all cases, stress is laid on the importance of strain. A discussion of soil fertility in relation to pasture management is included, and it is pointed out that the objective of manuring is to maintain uniform botanical composition of a good pasture once established and not to promote violent floristic changes, which is too often the case in practice. Several important points regarding the management of grasslands are mentioned, and due emphasis laid on the conservation of fodder and the use of the mower as a grassland implement. Suggested ways in which research and demonstration plots in the various States of the Commonwealth might be laid down and organized are given.

Pamphlet No. 40.—"A Guide to the Seasoning of Australian Timbers—Part 1," by C. Sibley Elliott, B.Sc., Division of Forest Products.

As a result of the constantly increasing interest being given in Australia to kiln-seasoning, the Division of Forest Products receives so many requests for drying-schedules for specific Australian timbers that it has been decided to publish, in a collected form, such information in this regard as is available. That action has been taken in the Council's Pamphlet No. 40. The publication discusses the seasoning of seventeen timbers, including two exotic timbers grown in Australia, namely, insignis or Monterey pine and willow.

Pamphlet No. 41.—"The Grading of Western Australian Timbers. Report on, and suggested Specifications for, the Grading of Jarrah and Karri, based on Investigations in 1932," by F. Gregson, B.E., and R. F. Turnbull, B.E.

This publication covers a co-operative field study extending over the latter half of 1932 on the grading of jarrah and karri with a view to the preparation of suitable grading rules to cover the supply of major products in these timbers. Recommended grading rules and specifications are given for all sizes of jarrah ordinary building and construction timber, jarrah flooring, jarrah and karri mine lift guides, karri cross-arms and jarrah paving blocks. Field studies on the relation of cutting sizes to nominal sizes and variation in sawing are also dealt with, and tentative recommendations are made showing what are considered to be reasonable allowable variations in sawing.

Pamphlet No. 42.—"Meteorological Data for Various Localities in Australia" (in co-operation with the Commonwealth Meteorological Bureau).

For some time past, scientific investigators throughout Australia have made extensive use of the meteorological data collected by the Commonwealth Meteorological Bureau of the Commonwealth Department of the Interior. Such data have been of value in a number of directions, and especially in connexion with researches concerning many different subjects in the fields of soils, entomology, plant industry, animal health, &c. In co-operation with the Bureau, this Pamphlet has accordingly been issued. It gives details of the normal mean maximum temperatures, the normal mean minimum temperatures, the normal mean relative humidities, and the average rainfalls in points for some 380 odd selected meteorological stations throughout the Commonwealth. The subject-matter of the publication has been arranged in meteorological divisions, and the stations for which data are given have been selected from the point of view of their being as representative as possible.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 74.—"Observations on Soil Moisture and Water Tables in an Irrigated Soil at Griffith, New South Wales," by E. S. West, B.Sc. (Adel.), M.S. (Calif.).

Bulletin No. .—"A Soil Survey of the Hundreds of Laffer and Willalooka, South Australia. Report of the Division of Soils." Edited by J. K. Taylor, B.A., M.Sc.

Pamphlet No. 43.—"Investigations on the Buffalo Fly, *Lyperosia exigua* de Meij.," by G. L. Windred, B.Sc. Agr. (and in part by Dr. B. J. Krijgsman).

(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 6.

NOVEMBER, 1933.

No. 4.

Citricultural Research.

Investigations at the Commonwealth Research Station, Griffith.

By E. S. West, B.Sc. (Adel.), M.S. (Calif.)

1. Introduction.

The Commonwealth Research Station, Griffith, was established in 1924 on an area of 57 acres situated in a central position 3 miles from the town of Griffith, and made available by the Water Conservation and Irrigation Commission of New South Wales, which initiated the movement for the establishment of the Station, and which has, since its inception, contributed towards its upkeep. The Commission is kept in touch with the work through a liaison officer. In addition to the Commission, the local settlers at Griffith have also helped in the work in various ways, in the early days through a body they had set up and known as the Murrumbidgee Irrigation Areas Research Bureau, and lately through a local Advisory Committee.

The Station is surrounded by some 829 fruit-growers who have between them some 4,830 acres planted to citrus. In addition, many of the results of the Station will naturally be applied to other citrus-producing areas of the Commonwealth.

An account of the early work of the Station was given some years ago (see this *Journal*, 1: 95 and 353). Since that time, further progress has been made in various directions, the more important of which are indicated in the paragraphs that follow.

2. Present Organization of Station.

Equipment.—From time to time in the past few years, small additions have been made to the buildings and equipment of the Station. The most important of these has been a small chemical laboratory where the necessary analyses of soils, &c., can be carried out. Of late, the Station has also served as the headquarters of an officer of the Division of Soils who has been making soil surveys in the Areas.

The following buildings now exist on the Station:—A chemical laboratory, equipped for soil chemistry and consisting of five rooms, a store-room, and a dark-room; a small detached iron building, consisting of a soil storage and preparation room and a still room; three residences for members of the staff; an implement shed and workshop; stables; an old weatherboard building of four small rooms used as a store-house; and a large spray irrigation plant. The laboratory and cottages are fitted with electricity, water supply, and sewerage services.

Certain meteorological observations have been taken at the Station since its inception, but in 1931 it became the Commonwealth Meteorological Bureau's official recording station for the Griffith district.

Arrangement of Planted Area.—The area of the Station amounts to nearly 60 acres (of which 50 are irrigable). The area is divided up into fields as per the plan in Fig. 1. Of the area available, about 30 acres have been planted to citrus, 10 acres to lucerne, and another field of 10 acres has been partly utilized for experiments in tick bean seed production.

Staff.—The present staff of the Station is as follows:—

Officer-in-Charge	..	Mr. F. S. West, B.Sc. (Adel.) M.S. (Calif.)
Field Research Officer	..	Mr. R. R. Pennefather, B.Agr.Sc. (Melb.)
Chemist	..	Mr. A. Howard, M.Sc. (Melb.)
Orchard Superintendent	..	Mr. B. H. Martin, Dip. Hawk. Coll.
Farm Foreman	..	Mr. T. J. Masters.
Clerical Assistant	..	Miss E. Beck.
Liaison Officer (C.S.I.R. and W.C.I.C.)		Mr. F. K. Watson, M.A., B.Sc.Agr., B.Sc. (Eng.), A.M.I.C.E. (London), A.M.I.E. (Aust.).

3. Present Investigations.

In the spring of 1924, the three original fields were planted, namely, (i) a soil treatment field, (ii) a green manure experiment field, and (iii) a fertilizer field. These were designed to answer the cultural questions that appeared most urgent at the time, but the work of the Station has since developed in other directions as well. All the trees in these fields were raised from selected buds of Washington Navel parent trees and Late Valencia parent trees. Experience has shown that the choice of buds was very satisfactory, as fruit from the different trees is of a uniformly good quality and size.

Soil Treatment Field.—At the time of the establishment of the Station, great difficulty existed in the management of the heavy retentive soils which made up a considerable portion of the Murrumbidgee Irrigation Areas. During wet winters, and particularly that of 1923, trees died through water-logging of the soil, cultivation of the soil seemed to be difficult, and it was considered that the impervious nature of the clay band which underlay the surface soil prevented the proper penetration of the roots of orchard trees and also the penetration of irrigation water. Successful management of such soils, therefore,

seemed to be the most pressing necessity of the moment, so that plots were laid out in this field to test the possibility of overcoming these difficulties by the use of tile drains, deep ploughing, subsoiling, and by applications of lime and of gypsum.

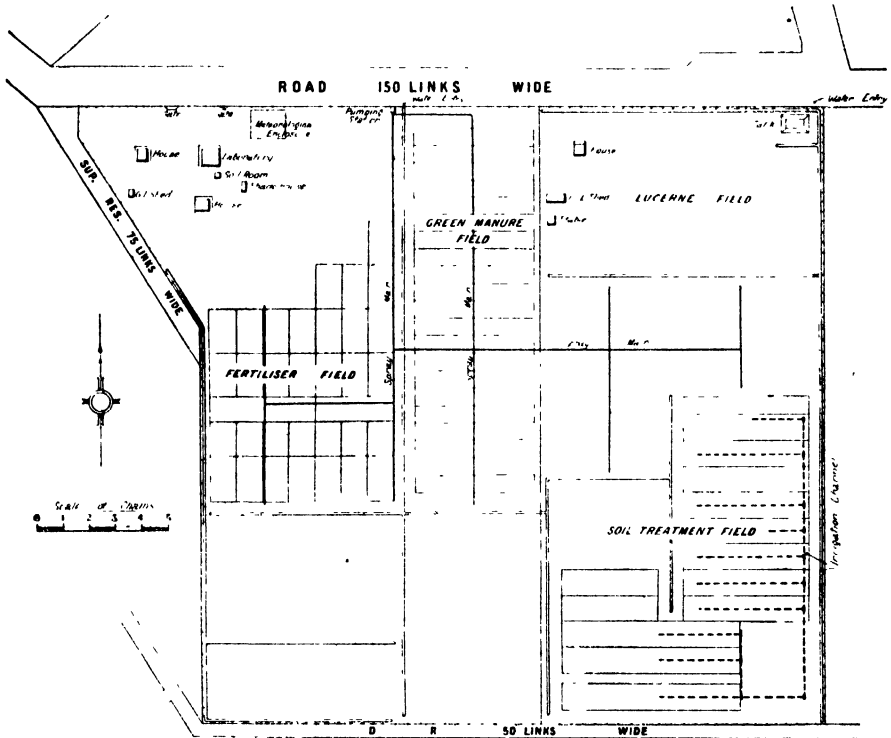


FIG. 1.—Plan of the Commonwealth Research Station, Griffith, N.S.W.

The work of the Station and of the Irrigation Commission goes to show that these troubles can be controlled by simple and less expensive methods. Thus a high water table can be easily lowered by growing deep-rooted green crops between the citrus trees. Then again it has been found that by improved methods of irrigation, water-logging can be prevented, so that the problems associated with these heavy retentive soils have largely been overcome.

Green Manure Field.—Five green manure treatments were originally selected, namely:—

- (1) Summer green manure crop (cowpeas).
- (2) Winter green manure crop (tick beans).
- (3) Biennial green manure crop (Bokhara clover).
- (4) Perennial green crop (lucerne) .
- (5) Continuous clean culture as a control.

Results have now been obtained over a sufficient number of years on which to base reliable conclusions. Very early during the growth of the trees, it was noted that those on the winter green manure plots were making better headway than the others. Later, it was noted that

trees in the summer growing crop plots, viz., cowpeas and lucerne, were growing more slowly than those on the clean cultivated plots. Using the diameter of the butts of the trees as an index to size, it has been found that the trees on the winter green manure crop plots are larger than those on any other plots, and the yield is about 30 per cent. more than on the continuously clean cultivated plots. The yield and size of the trees on the cowpeas plots are below those on the continuously clean cultivated plots, while the yield and size of the trees on the lucerne plots are the lowest of all, being only 66 per cent. of the clean cultivated plots, or half that of the tick-bean plots. Evidently, the competition between the summer growing green crops and the trees for water and perhaps minerals is so great as to more than offset the advantages of the added organic matter. In fact, although every endeavour is made to keep these plots properly supplied with water during the summer time, which necessitates the use of three or four times the quantity of water applied to the other plots, the soil of the plots cannot be maintained in the best moisture condition.

The seed for suitable leguminous crops is expensive, and the question arises as to whether it would not be cheaper to grow a crop such as barley and make up the difference in nitrogen by adding an artificial fertilizer. However, as a reasonably good crop of tick beans returns an amount of nitrogen to the soil over and above that of a reasonably good crop of barley equivalent to a dressing of 7 cwt. of sulphate of ammonia, it is considered that the leguminous crop is a cheap form of ammonogenous manure, without considering the organic matter.

The nitrogen question is an important one, particularly with citrus that is affected so much when nitrates are deficient. It is recognized that the decay of organic matter low in nitrogen leads to a temporary loss of soil nitrates, whereas the decay of nitrogen-rich organic matter probably leads to a quick formation of nitrates. The nitrate content in both the tick bean plots and the clean cultivated plots is therefore being followed week by week. The investigation has just begun, but promises to yield interesting information. It is hoped to extend the work to include the cowpeas plots later, as on these plots the legume is growing and the green stuff decaying at different seasons of the year from those of the tick beans.

After several years of persistent growth and turning under of green manures, it is now observed that the structure of the soil has been definitely changed. A different type of cracking occurs on the green manure crops from the clean cultivated crops, but what is of more practical importance, it is being found to be increasingly difficult to get sufficient water to soak into the clean cultivated plots at irrigations, whereas the green manure plots still absorb water quite readily. It is a very common observation that, after the soil has been cultivated and irrigated for several years, the structure deteriorates, e.g., soil that once appeared loose and open becomes stiff and compact. Evidently, the annual growth and turning under of green manure is a remedy or preventative, and for this reason alone the use of green manure is desirable.

Since 1928, when the value of tick beans as a winter green manure was first established by this experiment, the use of such beans throughout the Areas has doubled itself in every succeeding year, so that now it is rapidly becoming a standard practice of the district.

The Station is at present giving some attention to other winter legumes, for example, Berseem clover, lupins, tares and tick beans, tares and barley, field peas and tick beans, and field peas and barley, to ascertain whether tick beans alone can be improved on. Trials are also being made in regard to the question of growing tick beans locally for seed in order that the existing cost of seed to growers may be reduced.

Mineral Fertilizers.—The original mineral fertilizer field was established to ascertain the relative values of the following treatments:—

1. Nitrogen, phosphoric acid, and potash.
2. Nitrogen and potash.
3. Nitrogen and phosphoric acid.
4. Phosphoric acid and potash.
5. Nitrogen.
6. Potash.
7. Phosphoric acid.
8. No fertilizer.

Up to date, no significant differences in the size or yield of the trees are noticeable. This is rather surprising, in view of the very early benefit found from green manuring. Evidently, the organic matter added to the soil is important to the plant, apart altogether from the nitrogen.

It has been noted that the trees on all the plots receiving superphosphate develop a mottling, regardless of whether or not nitrogen or potash is added as well.

Experiments carried out on older groves have shown that citrus trees respond to heavy dressings of nitrogenous fertilizers, and these experiments have led to the extensive use of sulphate of ammonia on mature trees throughout the Areas.

Bud Selection.—Judging from the results that have been obtained with the selected trees of the Station, there is reason to believe that much of the trouble often met with in young Navel oranges is due to inferior types. Many of these types are characterized by large coarse-skinned fruit, which characteristic is greatly intensified when the tree is young or is making great vegetative growth. The true Washington Navel type also shows this tendency but to a much less extent, so that the fruit is not very coarse even when the tree is young.

Phosphatic Fertilizer Experiment with Lucerne.—In the autumn of the year 1926, an experiment concerning the phosphatic manuring of lucerne was commenced. Plots receive annual dressings of 1 cwt., 2 cwt., and 4 cwt. of superphosphate per annum. There are also plots in which 1 ton of rock phosphate per acre was applied as an initial dressing only. The yields, while increasing with the amount of superphosphate, have also shown that dressings heavier than 4 cwt. would still be profitable. Unfertilized lucerne proved almost a failure, and the stand practically died out in two years. After six years, the stand of lucerne in the 1 cwt. plots still exists, but it cannot be said to be a good one. The stands in the 2 cwt. and 4 cwt. plots are good, but the latter yields about 7 tons of hay compared with 4 tons from the 2 cwt.

The behaviour of the rock phosphate plot has been interesting. The first year the yield was equal to that of the 1 cwt. superphosphate dressing, the second year it was better than the 1 cwt. dressing, and since then has been practically equal to the 2 cwt. superphosphate dressing.

Ripening of Oranges.—By determining the acid content of the juice and noting the colour of the rind of the oranges from the differently treated plots, some idea of the effect of different treatments on the ripening of the fruit is being obtained.

During the 1932 season, it was found that, in the green manure field, trees on the tick bean plots and clean cultivated plots coloured earlier and contained less acid than the trees on the Bokhara clover plots and lucerne plots; that is the larger and more vigorous the trees the earlier they coloured and lost their acidity.

Results obtained during the present season have confirmed this; in fact, the differences have been more striking, but as the season has a great effect on ripening, it is possible that it may be found that these effects are either intensified or otherwise in subsequent seasons.

Soil Moisture Investigations.—Whilst crop control of excess water and salt can prevent much damage, especially in certain badly situated areas, it early became evident that most of the trouble could be prevented at its chief source, viz., the actual application of irrigation water. In the early days of the Areas, scarcely any data were available for guidance, and excessive waterings were generally the rule. Accordingly, the Station has given considerable attention to the fundamental problems of the relationships between soil and moisture, and to such soil constants as the "wilting coefficient," "sticky point," and "field capacity." This work is facilitated by test wells (2 in. auger holes 11 ft. deep protected with casings of perforated down pipe) that are distributed throughout the various fields, and by means of a self-recording test well installed in a column of soil 1 metre in diameter and 6 metres deep isolated *in situ* and enclosed in an impervious jacket. The water table in the soil column is controlled by adding rain water to the surface of the soil in amounts and at times that circumstances indicate.

It has been found that the water table in soils is very sensitive to changes in atmospheric pressure and in soil temperature. Thus a lowering in the atmospheric pressure causes a rise of the water table as does an increase in the soil temperature. It is due to the first-mentioned of these effects that the increased flow of springs and seepages during the passage of cyclones is due.

In field studies involving the evaluation of the moisture content of the soil, a great difficulty is the large sampling error involved owing to the big variation in the physical texture in soils, which may, nevertheless, appear quite uniform. The use of the "sticky point" has been developed to correct for the error due to the variation in soil texture. The sticky-point is that moisture content of the soil at which the plastic mass just fails to adhere to external objects, and can be easily determined with sufficient accuracy. It has been found that with Griffith soils, the sticky point closely approximates the "field capacity," or that quantity of water that remains in the soil in the field after water has been added and approximate equilibrium conditions have been

attained. By subtracting the actual moisture content from the sticky point, we find the amount of moisture that must be added to the soil to again bring it to the field capacity, regardless of the texture of the soil. By this procedure, the precision of field moisture determinations is greatly increased.

The work at Griffith relating to the soil and its moisture content, results of which have been published as the Council's Bulletin 74, together with the intensive work carried out by the Irrigation Commission on the question of seepage and waterlogging, has had a very great influence on the irrigation practices of the Murrumbidgee Irrigation Areas. It is now generally recognized that care is necessary in handling water if the soils are not to be damaged, and very great advances are noticeable in the general irrigation methods and outlook of the local settlers.

Irrigation Methods.—The methods of applying irrigation water to the soil by means of flooding in various ways and by overhead sprays have been investigated for some time.

Amongst the surface methods, that depending on the application of water by allowing it to flow down furrows is perhaps the cheapest and easiest, but, in some types of soils, difficulties arise owing to excessive soaking at the top end of the furrow and to unequal wetting of the soil in the furrows and between the furrows. By increasing the number of furrows till they form a series of ridges and hollows from tree to tree, by suitably limiting their length, and by other modifications, these objections can be largely overcome. This work, however, necessitates the development of implements than can draw furrows under the foliage of trees. In co-operation with manufacturing firms, an endeavour is being made to design equipment for this purpose.

A second method of surface irrigation, namely, the border method, in which water flows down between low levees or borders, gives the required control over water, but it is difficult where the land slopes across the line of watering as well as down the line. For this reason it is not always applicable.

In the basin method, whereby the land is divided by levees into small basins, absolute control over the water is possible. Here again, however, rather level land is necessary, and the labour and cost of forming the levees may be too high for local conditions. Nevertheless, the method is being investigated.

The spray method of irrigation gives absolute control of the water applied under all circumstances, but the cost of its initial installation is rather high. Work aimed at the improvement of the existing apparatus, and the reduction of its initial cost, is in progress at the Station. The equipment under test was designed by a local grower, and is known as the "Kook" equipment after his name.

The previous initial cost of the equipment has already been reduced, and has been brought within the range of commercial practice. As a matter of fact, at the present time eleven large scale growers have installed overhead spray equipment on their blocks.

During the present (1933) winter, it is intended to investigate the effects of varying the lengths of laterals, spacings of perforations, size

of perforations, and pressure of water, so that graphs may be drawn to obtain information enabling the most economical equipment for any particular farm to be designed.

Other Investigations.—In addition to the foregoing work, the Station has a few other investigations in hand.

The effect of a soil mulch on moisture conservation and on soil temperature has been studied, and the results of this work have been published (see this *Journal* 3: 97, 1930, and 5: 236, 1932).

The Station's work on frosts carried out in association with the Irrigation Commission has demonstrated that the close proximity of mallee scrub is conducive to frost formation; the results have also been published (this *Journal* 4: 173, 1931, and 6: 80, 1933). Methods of protecting young citrus trees from frosts have been investigated, and it has been found that wrapping the stems with newspapers and mounding up with soil is a useful protection. It is also of great importance to maintain a vigorous growth during the summer.

On the Murrumbidgee Irrigation Areas, the Valencia orange possesses the objectionable habit, well known in many varieties of fruit, of bearing alternate heavy and light crops. This not only causes serious marketing difficulties, but the quality of the fruit also suffers. Undoubtedly the same general principles are at work here as in other fruit, such as the apple, but the details differ, as the period between fruit bud formation and setting in the orange is the matter of a few weeks only. It seems significant that the fruit of one seasons' crop of Valencias is still on the tree when the next season's crop is setting. The question is being investigated in co-operation with the Division of Plant Industry.

Finally, the post-war expansion of the Australian citrus industry has entailed a greater amount of attention being given to marketing problems, particularly those of the storage and transport of the fruit. The great bulk of Australia's citrus exports are derived from the Griffith district. The Station is, therefore, in a particularly favorable position to study many important features of the problems in question, particularly from the point of view of the effects of conditions in the groves. Cool storage tests with Navel oranges are now being carried out by the Station on behalf of the Citrus Preservation Committee. The necessary storage facilities have been made available by the Griffith Producers' Co-operative Company Limited.

The Use of Carbon Dioxide in the Storage of Chilled Beef.

By W. A. Empey, B.V.Sc.,* and J. R. Vickers, M.Sc., Ph.D.†

The work described in the article that follows forms part of the programme which is being carried out by the Council's Section of Food Preservation and Transport in co-operation with the Queensland Meat Industry Board. The lines of that co-operation and some details regarding the programme itself, have been given in a previous issue (this *Journal* 5: 133, 1932). Briefly, the Meat Industry Board has provided the buildings and equipment for the Section's laboratory at the Brisbane Abattoir, Cannon Hill, Brisbane, while the Council is supplying and maintaining the necessary research workers.—Ed.

Summary.

Under the conditions in which the experiments were carried out, attack on the moist superficial tissues by bacteria—mainly various strains of *Achromobacter*—has been the chief cause of wastage in chilled beef stored for prolonged periods. Deterioration caused by the growth of moulds has been relatively insignificant, due mainly to the fact that moulds have constituted an extremely small percentage of the initial contamination.

2. The duration of safe storage, both in carbon dioxide and in air, was largely determined by the numbers of bacteria acquired by the beef during dressing and initial chilling and capable of relatively rapid proliferation at a temperature of -1°C . (30.2°F .).

3. The extent to which small concentrations of carbon dioxide, of the order of 10 to 12 per cent., in the storage environment restricted the rate of growth of *Achromobacter* determined the length of storage possible without appreciable deterioration occurring in the beef, and this period was approximately 40 per cent. greater than that possible under similar conditions of storage in air.

4. Beef obtained from meat works in which *Achromobacter* constitutes the main type of initial infection, may safely be held in the chilled condition for a period of 53 days (approximately equivalent to a period of transport of 45 days), provided that strict hygienic conditions are maintained during slaughter, dressing, and chilling, in order to ensure an extremely low bacterial infection, and provided also that concentrations of carbon dioxide, of the order of 12 per cent., be employed in the storage environment.

1. Introduction.

For countries regularly engaged in a chilled beef trade with Great Britain, the duration of the voyage seldom exceeds 25 days, but the corresponding time from Queensland, which contributes rather more than 85 per cent. of Australia's exports of quarters of beef, at present exceeds 50 days. Since about five days for the preparation of the beef in the meat works, and about three days for its marketing, must be added to this period, the average duration of holding of chilled beef exported from Queensland is likely to be of the order of 60 days. Only a small margin of safety exists in the export of chilled beef from countries nearer to Great Britain. It therefore seems fairly certain that, in

* An officer of the Council's Section of Food Preservation and Transport

† Officer-in-Charge, Section of Food Preservation and Transport.

order to secure reasonable freedom from wastage, a somewhat different technique from that used by Australia's competitors must be employed in the export of chilled beef from the northern States of Australia.

Investigations carried out in Great Britain, Germany, and the United States of America, and confirmed in this laboratory, have shown that deterioration of beef during storage at temperatures close to the freezing point of the meat, -1°C . (30.2°F .), is due almost wholly to the proliferation of certain species of bacteria and moulds on the superficial tissues of the quarters. The extent of deterioration during storage therefore depends both on the degree of contamination of the beef by low-temperature type bacteria and moulds* during slaughter, dressing, handling, chilling, and storage, and on their rates of proliferation during chilling and storage. As investigations on the first factor, discussed in detail in subsequent sections of this communication, have shown that the adoption of simple precautions will reduce, but not wholly eliminate, the initial microbial contamination, adequate control of the rates of proliferation of the "low temperature type" species during chilling and storage is therefore essential.

Brown(2) showed that relatively high concentrations of carbon dioxide in the air of the storage environment gave complete inhibition of the growth of many species of moulds, and Killifer(7) found that the duration of storage of many types of fresh meat products could be greatly prolonged by the use of relatively high concentrations of carbon dioxide. The maintenance of high concentrations of this gas—say 50 per cent.—in ship's holds and other stores presents almost insuperable difficulties, and, therefore, detailed studies of the effects of relatively low concentrations on the growth of "low temperature type" moulds and bacteria have been carried out by many investigators working in the laboratories of the British Food Investigation Board (3, 4, 5, 9, 10). These studies have shown that concentrations of carbon dioxide, of the order of 10 to 20 per cent., produce an inhibitory effect on the growth of most micro-organisms commonly found on meat and fish.

As it was impossible to anticipate the problems involved in projecting the results of laboratory and small-scale experiments to a commercial scale, experiments, wherein quarters of beef were stored in atmospheres containing 10 to 12 per cent. carbon dioxide, have been carried out under strictly controlled commercial conditions, in conjunction with a large meat exporting works. The use of carbon dioxide during initial chilling of beef to the temperature of storage being impracticable, its effects during storage only have been studied.

2. Experimental Procedure.

(i) *General*.—Six bodies of beef of average quality were employed in each experiment, and the customary abattoir procedure for their dressing, handling, and chilling was followed. In the first experiment, however, the beef was chilled in a large commercial room, and, in the second, in a small experimental chamber. After the completion of chilling to a uniform temperature of 0°C . (32°F .), the sides were divided into quarters which were covered with sterilized stockinette, and placed in two storage chambers cooled by overhead grids of brine pipes and

* Bacteria and moulds capable of comparatively rapid growth under suitable conditions at temperatures of the order of -1°C . (30.2°F .) will subsequently be referred to as "low-temperature types."

maintained at similar temperatures and relative humidities. The construction of these chambers was similar in all respects, except that one was made "gas-tight" to enable uniform concentrations of carbon dioxide to be maintained in its atmosphere. Comparable experimental material was obtained by placing the twelve left quarters in the "gas" chamber, and the twelve opposite quarters in the control chamber.

Only the main features of the experimental procedure are described.

(ii) *Physical Conditions*.—Losses of weight during chilling and storage were obtained. In Test 2, the extent of superficial desiccation of exposed muscle tissue was determined by measuring the moisture contents of successive 2 mm. layers taken immediately after chilling and at the completion of storage from four exposed areas of muscle in the vicinity of the aitch bone of the hindquarters; the observations had to be limited to this region owing to its comprising the bulk of the small area of exposed muscle available on each side of beef. From time to time the moisture contents of the first half millimetre (outer) layer of exposed muscle were determined.

During the progress of chilling, continuous observations were made of the average temperature, relative humidity, and rate of movement of the air, and of the rate of reduction of the temperature of the deep and superficial portions of the meat.

Observations of the temperature, relative humidity, and concentration of carbon dioxide in the atmosphere of each chamber, and of the temperature of the superficial portions of the meat, were carried out twice daily, and were so determined as to obviate the necessity of opening the chambers, except at such times as detailed examination of the meat was desirable. The temperatures of the air and of the meat in each chamber were determined at six and three positions respectively. While cold brine was circulating through the grids of pipes, the concentrations of carbon dioxide at different positions in the chamber did not vary from the mean value by more than ± 0.1 per cent.; the concentration at one point only was therefore determined.

(iii) *Sampling for Microbial Examinations*.—Since deterioration affected only the superficial tissues, samples of exposed muscle and adipose tissue, each 2 sq. cm. in area, were excised to a depth of 2 mm. for the determination of the type and numbers of the microbial population. The initial sampling was carried out within one or two hours of slaughter, six areas each of exposed muscle and adipose tissue being removed, under aseptic conditions, from each of four sides of beef; the 24 samples of muscle and of adipose tissue were combined in order to give an average value of the microbial contamination of each type of superficial tissue. Similar samples from contiguous areas were removed, in one experiment, at the completion of chilling, and, in both experiments, on several occasions during storage. The percentage of "low temperature type" micro-organisms present in each group of samples was determined by comparing the numbers of organisms viable on artificial media at incubation temperatures of 20° C. (68° F) and -1° C. (30.2° F).

(iv) *Sampling for Examination of Fat*.—At the completion of chilling and of storage, three samples of superficial fat, each 2 mm. thick

and 40 sq. cm. (approx.) in area, were removed from the back, abdominal, and neck-thorax regions of six quarters. The 18 samples of each group were subsequently minced and ground in a mortar to secure intimate mixing. At the completion of storage, samples were also obtained from areas heavily infected by either bacteria or moulds. Estimations of the acid values of the extracted fat and degree of rancidity of the "native" fat, determined by the measurement of the "active" oxygen value described by Lea (8), were carried out on each of the mixed samples. "Blind" palatability tests, by three observers, on hot and cold portions of each of the mixed samples of fat served to detect the presence of "off" flavours. For these tests, tissue sampled immediately after the completion of chilling was stored in stoppered bottles at a temperature of -17°C . (1.4°F .) pending the comparison with the samples obtained at the completion of storage.

3. General Observations on Storage Experiments.

(i) *Physical Data*.—Table I. gives a summary of the physical conditions obtaining during the chilling of the beef (in sides). The duration of holding in the chilling rooms was 72 hours (approx.).

TABLE I.—SUMMARY OF THE PHYSICAL CONDITIONS DURING STORAGE.

Test No.	Mean Air Temp. $^{\circ}\text{C}$.		Mean Relative Humidity Centre Room.	Mean Vr (mm. Hg.).		Mean (Vm-Vr) (mm. Hg.).		Reduction of Meat Temperatures.		Air Movement. Time (mins.) for One Complete Change.	Weight Loss.	Original Moisture Lost. (Mixed S.M.)
	First 8 Hours.	Subsequent Cooling Period.		First 8 Hours.	Subsequent 24 Hours.	First 8 Hours.	Subsequent 24 Hours.	Deep But to Reach 5°C .	Av. Time Taken. (Hrs.) Mean superficial to Reach 10°C .			
1	2.3	-0.5	(%) 94	6.0	4.5	16.6	1.9	47	13	2.5	(%) 0.6	(%) 17
2	5.9	0.0	78	5.3	3.7	15.5	2.5	41	8	0.75	1.2	27

Vr = Aqueous vapour pressure at centre of room.

Vm = Saturation vapour pressure at mean superficial temperature of the beef.

S.M. = First $\frac{1}{4}$ mm. layer of exposed muscle. (Average moisture content fresh muscle is 75 per cent.)

The rate of cooling of the beef, particularly in the superficial areas, was considerably greater in Test 2 than in Test 1. In Test 2, the higher rate of movement and lower vapour pressure of the air is reflected both in the greater total loss of weight and in the lower average moisture content of the first half-millimetre (outer) layer of the exposed muscle.

The chief physical data observed during the storage of the beef are collected in Table II.

TABLE II.—PHYSICAL DATA DURING STORAGE.

Test No.	Duration of Storage (days).	Air Temp. ° C.			Superficial Meat Temp. ° C.			Mean Relative Humidity.	Vr (mm. Hg.).	Vm-Vr (mm. Hg.).	CO ₂ Concentration. (%)		Weight Loss Per 44 Days During Storage.
		Mean.	Mean Deviation.	Mean Spatial Difference.	Mean.	Mean Deviation.	Maximum Deviation.				Mean.	Mean Deviation.	
1.								%					%
"Gas" store	44	-1'0 ₀	0'1 ₅	±0'3 ₀	-0'9 ₀	0'1 ₀	+0'1 ₅ -0'2 ₀	96	4'1 ₅	0'1 ₅	10'2 ₅	0'2 ₅	2'2
Control Store	29	-1'0 ₀	0'1 ₀	±0'3 ₀	-0'8 ₅	0'0 ₅	±0'2 ₀	96	4'1 ₀	0'2 ₀	0'0 ₅	..	..
2.													
"Gas" Store	55	-0'9 ₀	0'1 ₅	±0'3 ₀	-1'0 ₀	0'0 ₅	+0'2 ₀ -0'1 ₅	93	4'0 ₀	0'2 ₅	12'1 ₀	0'4 ₀	2'7
Control Store	55	-0'9 ₅	0'1 ₅	±0'3 ₀	-0'9 ₀	0'1 ₀	±0'2 ₀	94	4'0 ₅	0'2 ₅	0'1 ₀	..	2'7
(x)													

(x) Eight of twelve quarters were removed after storage for 40 days.

Vr = Mean aqueous vapour pressure.

Vm = Saturation vapour pressure at the temperature of the surface of the meat.

As it was desired to prevent any undue formation of ice in the muscle tissue of the beef during storage, the mean air temperature could not be maintained lower than -1.0°C . (30.2°F .)—the average freezing point of beef muscle—particularly in view of the fact that the coldest part of the storage rooms had a steady temperature of -1.3°C . (29.7°F .). In such positions, after a period of storage in excess of 40 days, the quarters of beef invariably showed some formation of ice in the muscle tissue. The slight divergence of the mean meat temperatures from the mean air temperatures was due to there being an insufficient number of thermometers in the superficial tissues of the meat to permit the estimation of their true average temperatures.

In both experiments, no forced air circulation was employed during storage, other than that required for a period of ten minutes daily, while carbon dioxide was being added to maintain the requisite concentration. For purposes of comparison, the losses of weight of the quarters during storage, assumed to vary directly with time, have been reduced to a common basis of holding for 44 days; tests have shown this assumption to be reasonably accurate.

In Test 2, the average moisture contents of successive 2 mm. layers of exposed muscle after chilling were respectively, 55, 63, 69 per cent.; after storage, the corresponding values were 60, 64, and 67 per cent. respectively. During storage, the superficial exposed muscle had apparently acquired fresh moisture by diffusion from the deeper layers, and the superficial muscle was moister at the completion of storage than it was at the completion of chilling. The presence of bacterial slime on the exposed muscle of the beef after storage prevented this procedure being adopted in the first test.

(ii) *Microbial Contamination*.—Table III. gives a summary of the chief features of the average microbial contamination (excluding yeasts), per sq. cm. of exposed tissue, of the quarters of beef employed in the two tests.

TABLE III.—MICROBIAL COUNTS EXPRESSED AS NUMBERS OF MICRO-ORGANISMS PER SQUARE CENTIMETRE OF EXPOSED TISSUE.

Test No.	Tissue.	Time (days) Since Slaughter.	Count of "Low Temperature Type" Organisms.			
			Air Stored.		CO ₂ Stored.	
			Bacteria.	Moulds.	Bacteria.	Moulds.
1.	Muscle	0	550	<5	550	<5
		3	103,000	<50	103,000	<50
		31	18,000 x 10 ⁶	<1,000	800 x 10 ⁶	<100
		46	..	..	8,000 x 10 ⁶	<500
	Fat ..	0	250	<5	250	<5
		3	32,000	<40	32,000	<40
		31	100 x 10 ⁶	<200	70 x 10 ⁶	<50
		46	..	..	500 x 10 ⁶	<100
2.	Muscle	0·3	56	<1	56	<1
		21	80,000	16,000	400	<10
		42	1.5 x 10 ⁶	0.1 x 10 ⁶	0.02 x 10 ⁶	<100
		57	150 x 10 ⁶	1 x 10 ⁶	0.4 x 10 ⁶	<1,000
		57 + 2 at 10° C.	..	..	30 x 10 ⁶	..
	Fat ..	0·3	30	<1	30	<1
		28	2,000	200	200	<10
		42	100,000	10,000	6,000	<50
		57	1 x 10 ⁶	0.1 x 10 ⁶	0.02 x 10 ⁶	<500
		57 + 2 at 10° C.	..	..	12 x 10 ⁶	..

In each test, visible microbial contamination first appeared as small, moist, bacterial colonies in the form of nodules, situated usually in the moister areas of exposed muscle on the neck, the residual tissues of the abdominal aorta, and beneath the diaphragm. During chilling and storage, the neck and aortal areas receive some drainage of blood and lymph from the adjacent vessels.

As the duration of storage increased, these colonies tended gradually to coalesce and to form "slime," which was invariably accompanied by a sour, stale odour. This point of definite onset of deterioration invariably occurred when the number of "low temperature type" bacteria per sq. cm. of exposed muscle was of the order of 5×10^7 , an observation which agrees reasonably well with that of Haines(6), who specifies that the "slime" stage is reached in moist muscle when the number of organisms per sq. cm. is approximately 3.2×10^7 . The times from slaughter required for such development in Test 1 were 23 and 16 days for the beef stored in carbon dioxide and air respectively, while the corresponding times in Test 2 were 67 (estimated) and 45 days

respectively. In Test 2, the "slime" stage was not reached at the conclusion of storage in 12 per cent. CO_2 —57 days from slaughter—and the value given above has been estimated from bacterial counts. In Test 1, the onset of deterioration subsequent to the "slime" stage was marked by more extensive spreading and an increase in the size of the colonies in the areas of muscle where visible growth had first become apparent, and it was marked also by the appearance of similar slime on the relatively drier areas of muscle, on the connective tissue covering the abdominal and thoracic cavities, on the fat covered by moist connective tissues, and on the moist surfaces of the rib muscles exposed as the result of the division of sides into quarters.

An analysis of the species of "low temperature type" bacteria found initially on the surfaces of the beef showed that several types belonging to the genus *Achromobacter* Bergey, *et al.*, constituted at least 95 per cent. of the infection, and that the remainder consisted of several species of *Pseudomonas* and *Micrococcus*. During the subsequent development of nodules and slime, the relative percentages of *Achromobacter* and *Pseudomonas*, both on the beef stored in carbon dioxide and on its control stored in air, tended to increase at the expense of the slower growing *Micrococcus*.

An examination of the data given in Table III. shows that the extent of the restriction of bacterial proliferation, caused by the use of 10 to 12 per cent. carbon dioxide, varies considerably at different stages in the period of storage. From the point of view of the safe storage of chilled beef, however, the extent of inhibition up to the time of initial slime formation is obviously of paramount importance, and, during this period, the carbon dioxide has effected a reduction of 40 per cent. (approx.) in the rate of proliferation. Comparisons of the growth rates of *Achromobacter* (several strains) and *Pseudomonas* on plates of nutrient agar in atmospheres of 94 and 99 per cent. relative humidities, determined according to the method described by Coyne(4), showed that 10 to 12 per cent. carbon dioxide caused an inhibition of 30 to 40 per cent. at the stage when growth became abundant, and thereby confirmed the observations made directly on the beef.

In Test 2, the effect of holding beef for two days in ordinary atmospheric conditions (mean temperature 10°C . (50°F .) subsequent to its storage in carbon dioxide was investigated. Although the bacterial count on the exposed muscle increased almost sixty-fold during this short period (see Table III.), the "slime" point was scarcely reached, even in the moister areas.

In all tests carried out in this laboratory—including many not described in this paper—the counts of "low temperature type" moulds per sq. cm. of exposed muscle and fat, obtained immediately after slaughter and after the completion of chilling, have been extremely low in comparison with the counts of "low temperature type" bacteria, and this condition has been reflected in the comparative absence of appreciable fungal attack, even after prolonged periods of storage. In the areas showing marked bacterial proliferation, fungal growth has invariably been absent.

In Test 2, after a period of storage of 42 days had elapsed, no visible colonies of mould were present on the beef stored in carbon dioxide, whereas the beef stored in air had an average population of 50 to 60

colonies, chiefly composed of *Penicillium expansum* with some *Sporotrichum carnis*. In the case of beef stored even so long as 55 days in 12 per cent. carbon dioxide, the number of visible colonies did not exceed three or four per quarter, and all proved to be *Sporotrichum carnis*. Since heavy bacterial contamination in all cases rendered necessary the disposal of the air-stored beef before mould colonies could be detected on the beef stored in carbon dioxide, it was impossible to make accurate estimates of the comparative rates of growth of the moulds on the meat in the two environments. Within the periods of storage so far investigated, 10 to 12 per cent. concentrations of carbon dioxide would appear, however, to have exerted an effective control of the growth of *Penicillium expansum*, and to have caused a moderate restriction of the growth of *Sporotrichum carnis* when compared with its growth on the controls stored in air. A quantitative determination of the comparative rates of growth of *Sporotrichum carnis* in air and in 10 per cent. carbon dioxide showed that the average times taken for the colonies grown on Czapek's agar to reach a diameter of 6 mm. were 27 and 36 days respectively, the temperature of storage and the relative humidity being $-1^{\circ}\text{C}.$ ($30.2^{\circ}\text{F}.$) and 99 per cent. respectively. The corresponding linear expansions, expressed in millimetres per 100 hours, were 1.2 and 0.9, respectively. These results indicate that the rate of growth of *Sporotrichum carnis* in 10 per cent. carbon dioxide is 70 per cent. (approx.) of that in air, an observation closely agreeing with that of Tomkins(10).

(iii) *Changes in Fats*.—The free acidities of various samples of fat, removed immediately after chilling and at the completion of storage, are given in Table IV. In all cases, their "active" oxygen contents did not exceed the equivalent of 0.3 ml. of 0.002 M. sodium thiosulphate, and therefore being extremely small, the values have not been recorded.

TABLE IV.—FREE ACIDITIES OF FATS AFTER CHILLING AND AFTER STORAGE.

Test No.	Sample.	Free Acidity (Per Cent.).					
		After Completion Chilling.	Control Stored 28 Days.	CO ₂ Stored 43 Days.	Control Stored 55 Days.	CO ₂ Stored 55 Days.	CO ₂ Stored 55 Days + 2 Days at 10° C.
1.	Back	0.51	..	2.15	..	..	..
	Abdomen ..	0.53	..	1.36	..	..	..
	Neck + Thorax ..	0.54	..	2.00	..	..	..
	Back, heavy bacterial contamination	..	1.69	..	..	..	..
	Abdomen do. ..	..	2.06	..	..	..	..
	Neck and Breast do.	..	1.95	..	..	..	..
2.	Back	1.53	..	..	2.65	2.02	..
	Abdomen ..	1.24	..	..	1.64	1.24	..
	Neck + Thorax ..	1.50	..	..	1.93	2.07	2.07
	Mixed, heavy bacterial contamination	..	..	..	2.84	..	..
	Mixed, heavy mould (<i>Penicillium</i>) contamination	..	..	..	2.45	..	..

Tests of the palatability showed that during storage in 10 per cent. carbon dioxide for a period of 43 days (Test 1), all samples developed stale odours and flavours variously described as "fishy" and acrid. All samples taken at the completion of storage (55 days) in Test 2 had developed slight "off" odours and flavours, but there were detectable differences only in the case of the fat taken from the neck and thorax areas of the air-stored beef, which had a rather more pronounced acrid flavour than that of the corresponding sample from the beef stored in carbon dioxide. Samples taken from quarters held for two days at a temperature of 10°C. (50°F.) subsequent to storage at -1°C. (30.2°F.) for 55 days showed no further development of "off" flavours. The mixed sample from the beef stored in air showing heavy bacterial contamination on the fat had developed an extremely pronounced acrid flavour. In the case of beef stored in carbon dioxide, there were no areas of fat heavily coated with bacterial slime.

The initial mean free acidity of the fat in Test 2 was 1.4 per cent., and at the completion of storage, it had risen to 2.1 and 1.8 per cent. for the air and carbon dioxide stored fats respectively. While the difference between the latter values is probably due to the development of heavy microbial contamination on the air-stored fat, thereby affording a useful index of the effects of microbial proliferation, the presence of the fatty acids alone, as Barnicoat(1) has shown, does not produce "off" flavours. These are probably due rather to attack by bacteria on the connective tissue of the fat than to any marked chemical changes in the glycerides themselves.

(iv) *Bloom of the Meat*.—The loss of bloom of chilled beef is, in some measure, proportional to the extent of the total loss of weight from slaughter to the completion of storage, and it has been found that if such losses exceed 5.5 per cent. (approx.)—the maximum allowable depends largely on the quality of the carcasses—the consequent loss of bloom is serious. In these tests, the losses of weight during periods of 46 and 57 days, from slaughter to completion of storage, have been 2.8 and 4.6 per cent. respectively. Except for the presence of a dull colour of the fat in areas covered with bacterial slime and the occurrence of slight darkening of exposed muscle, the bloom of the meat was not greatly impaired. This result was to be expected in view of the fact that the weight losses were considerably below the critical value. The presence of carbon dioxide did not appear to depreciate the bloom, either by affecting the colour of the fat or by causing a darker colour of the exposed muscles and a greater depth of penetration of methaemoglobin than in similar tissues in the beef stored in air.

(v) *Palatability of the Lean*.—The lean of beef stored in carbon dioxide had acquired a slightly tainted flavour only in exposed areas developing "slime" during storage. This condition, of course, applied only to Test 1.

4. Discussion.

While an insufficient number of experiments have been carried out to enable an accurate assessment to be made of the value of carbon dioxide in prolonging the safe period of storage of chilled beef, it is clear that the use of carbon dioxide will not, of itself, secure freedom from wastage during the period of the transport from Queensland to Great

Britain. It is desirable, therefore, to indicate generally some, at least, of the conditions to be adhered to in order that a trade in chilled beef reasonably free from wastage may be established.

The length of storage possible without the onset of wastage is largely dependent on the nature and degree of the initial contamination of the beef by "low temperature type" micro-organisms. While the maximum numbers of such organisms allowable per unit area of the beef cannot yet be specified, many experiments, not recorded in this communication, have indicated that by strict attention to cleanliness in every phase of the treatment of the beef in the meat-works, it is possible greatly to reduce the degree of contamination normally prevailing. A striking instance of the importance of this factor is revealed by the fact that, in the first and second tests, the ratio of the respective initial "low temperature type" contaminations per unit area of the beef was 10:1, while that of the respective durations of storage until the onset of the "slime" stage was 1:2.5.

Information is available concerning the effects of two factors operating during storage of the beef, viz., the temperature and the composition of the atmosphere. In order to restrict microbial growth, the temperature should be maintained as close as possible to the freezing point of the muscle tissue, -1°C . (30.2°F .). If some ice formation in the meat is not considered undesirable, however, the temperature may, with advantage, be reduced to about -1.5°C . (29.3°F .). For beef obtained from meat-works where the initial contamination consists chiefly of *Achromobacter*, the use of 10 to 12 per cent. carbon dioxide in the storage atmosphere produces an increase of 40 per cent. in the storage "life" of chilled beef compared with storage in air. The greater margin of safety secured, therefore, indicates the desirability of the use of this gas in ships' holds during the prolonged transport from Australia to Great Britain. Haines(5) has indicated that the use of 10 per cent. carbon dioxide almost doubles the time required for the production of a given number of *Achromobacter* organisms at 0°C . (32°F .); this divergence from the results recorded above may possibly be due to differences in the strains of organisms studied.

By experiments now in progress, it is hoped to define the optimum values of the factors responsible for the degree of superficial desiccation during storage, viz., density of stacking of the meat, relative humidity and rate of movement of the air.

In each stage of the treatment and storage in Test 2, conditions extremely favorable to prolonged storage were maintained. Not only was the initial count of micro-organisms extremely low, but the rate of reduction of temperature during chilling, and the degree of superficial desiccation were high. During storage, too, a rate of loss of weight approaching the limit defined in section 3 was employed in conjunction with the maintenance of a constant temperature of -1°C . (30.2°F .) and an atmosphere containing 12 per cent. carbon dioxide. With these conditions prevailing, the period of holding before the onset of appreciable deterioration, including the period at atmospheric temperature equivalent to the duration of the marketing of the

beef, was approximately 60 days. It seems doubtful, however, whether an initial contamination as low as that prevailing in Test 2 can be constantly maintained in large-scale commercial production. While it is difficult accurately to determine the effect of the probable average initial contamination under improved works' technique, it may be assessed tentatively as equivalent to a deduction of seven days from the storage "life" obtaining in Test 2. That is, when storage in carbon dioxide is employed, the probable maximum duration of holding of chilled beef is approximately 53 days, which is equivalent to a period of transport (storage) of 45 days. The latter period is somewhat less than the prevailing average duration of the voyage from Queensland ports to Great Britain.

These observations apply mainly to beef exported from works wherein *Achromobacter* is the predominating species in the initial "low temperature type" contamination. Owing to the fact that carbon dioxide is a relatively effective suppressor of the growth of the more common moulds, except *Sporotrichum carnis*, chilled beef exported from works wherein the former moulds comprise the bulk of the "low temperature type" contamination may reasonably be stored for a considerably longer period than has been indicated in the preceding paragraph.

5. Acknowledgments.

These experiments, and many others now in progress, have been rendered possible through the generous provision of laboratories and equipment by the Queensland Meat Industry Board. The investigators are also indebted to Messrs. Swift Australian Company Proprietary Limited for the loan of many bodies of beef.

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Blue Stain in *Pinus radiata* (*insignis*) Timber.

Some Preliminary Experiments with Case Stock.

By J. E. Cummins, M.Sc.*

Summary.

Owing to the increased consumption of locally-grown softwoods in Australia, the surface stains, which are caused by fungi and to which such timbers are susceptible, are important, particularly to the Australian case manufacturer.

Experiments aimed at the control of the stains by means of treatment with various solutions are described. Treatment with Lignasan (a proprietary material) effectively prevented blue stain development in case timbers even under bad stacking conditions. However, under such conditions, considerable development of surface mould occurred, but this could be effectively reduced by the provision of better foundations and thicker spacing strips in the stacks.

Treatment with soda solutions reduced blue stain development, but insufficiently for practical purposes. Mould development was also considerable. No experiments were made using improved stacking methods alone. In practice, better results would undoubtedly be obtained if the stacks were so built as to allow of more rapid drying of the timber.

1. Introduction.

Timber, particularly that of coniferous trees (softwoods) is susceptible to stains which may vary in colour from blue, pink, or green, to brown, yellow or black. These stains are either chemical or fungal in origin.

Chemical stains are generally caused by the reaction of some material with constituents of the wood sap, e.g., many Australian hardwoods contain tannin, and when they come in contact with iron, e.g., nails, a blue-black compound causing a characteristic ink-like stain is formed. Chemical stains do not cause serious degrade, and are usually removed when the timber is dressed. They are not further considered in this article.

Fungal stains are essentially different in nature and are of three general types, namely—(i) surface mould stains, (ii) wood-destroying fungus stains, and (iii) sap stains.

Surface moulds are generally green, blue, pink, yellow or black in colour, and are often characterized by a cottony or downy growth. They may sometimes appear powdery in texture, and are often confined to the sapwood only. They do not penetrate the wood and can be easily removed on surfacing. In stock which requires subsequent machining, they are not considered a defect, but in material such as case stock, they may cause serious degrade. In general, moulded cases should not be used for uncovered foodstuffs on account of the possibility of their contamination and subsequent breakdown. The development of surface moulds is often found in the kiln drying of green timber which requires initial conditions of low temperature and high humidity. When such moulds are seen developing in the kiln, they can be effectively killed by subjecting the charge to a steaming or high humidity treatment at 160°F. to 170°F. for one to two hours, the time depending on the effective circulation in the kiln. As well as discolouring the boards, such surface moulds are liable to interfere seriously with the circulation and cause uneven or retarded drying.

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Stains caused by wood-destroying fungi vary in colour. They may be present in the living tree, or they may develop in logs held in the bush or at the mill for long periods before conversion, or in timber stored under bad conditions. In general, they do not occur in yards in which good or relatively good seasoning practices are followed. They will not be discussed further in this article.

Sap staining fungi, as distinct from surface moulds, penetrate the wood and generally cause a blue or brown stain which cannot be removed by surfacing. It is this group of stains which causes tremendous losses in softwoods and minor losses in Australian hardwoods.

Sap stains which are blue in colour are common in hoop pine, kauri pine, bunya pine, and *Pinus radiata* (*insignis*), and some mills are experiencing considerable losses due to their action. Because of the increasing cut of Australian-grown pines, the problem of this sap stain prevention becomes of major importance, and it is proposed to conduct large scale experiments under Australian conditions in order to develop satisfactory methods for preventing or greatly reducing this form of degrade. The present article reports the results of some preliminary experiments on the prevention of blue sap stain in *P. radiata* case stock.

2. Sap Stains produced by Fungi.

Fungi may cause various types of stain particularly on the sapwood. Such stains are commonly bluish or yellow to brown, and different groups of fungi are responsible for the different discolourations caused. The stain which occurs on the sapwood of both hardwoods and softwoods, and which is bluish in colouration, is caused by representatives of several different genera of fungi, commonly called blue stain fungi. In Australia, no detailed investigation of these fungi has been made, but it is known from cultures prepared from infected wood that several species at least are present. Recently, Audrey M. Eckersley(1) has identified two forms closely related to *Ceratostomella pilifera* (Fr.) Winther and *Ceratostomella coerulea* Münch, from *P. radiata* grown on the Mornington Peninsula, Vic., and *Hormonema dematioides* Lagerberg and Melin from material grown at Macedon, Vic. The group of fungi causing the yellowish to brown sap stain in U.S.A., are often species of *Penicillium*, but no investigation of these has been made in Australia. However, some recent investigations have indicated that a species of *Cytospora* is responsible for a yellowish to brown discoloration in Tasmania myrtle (*Nothofagus cunninghamii*) sapwood.

Blue staining fungi chiefly inhabit the sapwood, and apparently feed principally upon the cell contents such as starch, sugar, &c., although some slight breakdown of the cell walls also occurs. As they develop, they penetrate deeper into the wood, and the fine fungal threads or hyphae pass from cell to cell chiefly in the medullary rays or parenchyma tissue. The passage from cell to cell is mainly through the pits or slit-like openings in the cell walls. In parenchyma tissue, more penetration of cell walls appears to take place than in tracheids, where passage from cell to cell is through the bordered pits. Examination of sections of badly blue stained wood shows apparent considerable breakdown of some of the ray cells.

In general, blue stain fungi do not penetrate the truewood,* but Lagerberg, Lundberg, and Melin(2) have recently reported cases where this definitely occurs. However, the extent of degrade due to truewood attack appears to be relatively small.

The newly-formed fungal hyphae are colourless, but after a few days they become coloured, and when blue stained wood is examined under the microscope, the hyphae appear yellowish-green to brownish-green in colour, although their effect is to cause the wood to appear bluish. Under certain conditions, and when the fungus has developed in the wood, its fruiting bodies can be seen as small black specks on the surface of the timber.

The conditions for the development of blue stain fungi are very similar to those necessary for the growth of other wood inhabiting fungi, particularly wood destroying varieties, but their effect on the timber is essentially different. For instance, they have only a slight effect on the strength of the timber, and, for general use, blue stained timber should not be rejected in the same way as that affected by wood-destroying fungi.

As conditions of development are similar, excessively blue stained material should not be accepted under conditions where strength is important, as typical decay fungi may also be associated with the blue stain. Further, blue stain generally indicates the presence of sapwood, and under conditions where resistance to decay is desirable, sapwood is not durable unless previously effectively treated with wood preservatives.

For their maximum development, blue stain fungi require food, moisture, air, and warmth. Food is provided by the sapwood of the tree, and ordinary weather conditions are suitable for development, although warm moist weather, as experienced particularly in northern New South Wales and Queensland, is conducive to rapid growth. Experiments by numerous investigators have shown that blue stain will readily develop at moisture contents of the sapwood (based on the oven-dry weight of the wood) ranging from about 35 per cent. to 120 per cent.(2), while growth may occur as low as 23 per cent. and as high as 150 per cent. The air requirements of the fungi are very small, but it is possible that growth at high moisture contents is limited chiefly on account of the restricted air supply due to complete filling of the cell cavities with sap.

Because of the ability of the sap stain fungi to develop satisfactorily over such a wide range, all timber is susceptible to attack at some time in its history. Blue stain is found in the living tree, the log, and the converted timber. In the living tree, infection is due to mechanical bark abrasion or the action of bark-boring or wood-boring insects which carry the spores on their bodies and spread the infection. Bark beetles and associated blue stain have been shown by Craighead(3) to cause the killing of pine trees in the United States of America. Logs left in the bush are susceptible to attack, particularly in warm moist seasons, and blue stain is frequently found extending from the end of logs and from places where the bark has been broken. The rapid removal of logs from the bush and their immediate conversion will do

* The term "truewood" has been adopted to describe what is usually termed heartwood. In Australia, the central portion of a tree is very often affected by decay or has little strength. This portion, which is really part of the heartwood, is called "heart." The terms "heart" and "heartwood" are therefore confusing, and that portion of the tree between the "heart," or the pith, and the sapwood has been named the truewood.

much to reduce the bluing. The use of sprays or end coatings is also effective at times, but this aspect of the problem needs much further experimental work before definite recommendations can be made. Sawn timber is particularly susceptible to attack, but efficient methods of piling can do much to control stain development. The obtaining of a dry surface by suitable provision for rapid initial drying and the maintenance of this dry surface is the basis of stain control during air seasoning. Kiln-drying of timber green from the saw will obviously reduce losses, but with certain classes of stock this is not commercially possible, and all mills are not equipped with kilns. Chemical dip treatments, as discussed later, are a further effective means of stain control.

Once timber has been infected, the spread of the stain may be very rapid. During periods of warm moist weather, it may completely penetrate the sapwood of logs or boards within a few days or weeks (see Plate 1).† Material bulk stacked when green can become seriously degraded within several days.

It appears that the slightly acid condition of the wood sap is particularly favorable for fungus development. The use of alkaline dips such as soda are based on this theory, the dipping rendering the surface of the wood alkaline. However, as soon as the alkali is more or less neutralized, staining is liable to occur if other conditions are suitable. Lignasan, a proprietary article* stated to contain 0.43 per cent. of ethyl mercury chloride, has recently been introduced into the timber industry in the United States of America as a sap stain preservative, and experiments carried out on both an experimental and commercial scale by various workers of the U.S. Bureau of Plant Industry (4, 5, 6, 7) have shown that good results have been obtained from its use. Sodium carbonate and sodium bicarbonate have both been used extensively for preventing sap stain, and, before the use of newer chemicals in the last few years, formed one of the commonly accepted standard treatments. (8) However, they have not given consistently good results, particularly under bad conditions of bluing.

Chemical dips are intended primarily to protect the timber during the early stages of drying and until the surface is below the moisture content at which stain will develop, but, even with their use, good piling practices are also essential.

Once timber has been dried below the danger point, it is not immune from further attack if it is allowed to become wet again, for the causal fungi can remain dormant for long periods pending the time when moisture conditions are again suitable for their growth.

3. Experimental Work in Australia.

Pinus radiata is at present largely used in Australia for case stock, but such stock is often cut at small mills utilizing hedge-grown material. In consequence, the shooks often receive little care in handling and are frequently delivered to the case manufacturer bundled green. However, conditions for their rapid drying are not always available to the manufacturer and air-drying space is often restricted. Under such circumstances, the development of blue stain all too frequently results.

† See facing page 308.

* Manufactured by the E. I. du Pont de Nemours Co.

One case manufacturer in Melbourne approached the Division with reference to prevention of blue stain which was occurring in his factory and causing serious losses. An inspection of the factory showed that conditions for blue stain development were very favorable, and, as the proprietor was agreeable to make a limited amount of material available, it was decided to initiate preliminary experiments.

Outline of Experimental Work.—At the factory, case shooks are received from various small mills on the Mornington Peninsula, Vic., the green stock being received within a few days of cutting. On receipt, the shooks are “lap” stacked* on the second floor of the factory. The practice was to build stacks right on to the floor, each stack two boards wide and about 6 feet high, leaving a central space in each stack of from 7 to 11 inches, the space depending on the width of the material stacked. Case sides were used for end strips. Spaces between stacks averaged about 18 inches. The floor has doors at each end, but, except when a strong north wind is blowing, the air circulation throughout the room would be very poor and irregular. Stacks were erected both parallel and at right angles to the direction of air flow between the doors.

It appeared that there were two ways by which improvement could be effected. Firstly, much could be done in the way of a more efficient stacking practice by the provision of suitable foundations, the use of thicker strips, and the laying out of stacks so as to take advantage of all the available air circulation. Secondly, the use of chemical dips with only slightly modified piling practice could be attempted; and it was decided to conduct the experiments with these and with modifications in stacking.

Materials for the Treatments.—A load of case sides (approximately 1,500 boards) of *P. radiata*, 21 x 7 x $\frac{3}{4}$ inches, were made available for the work. They were cut at Red Hill, Vic., the day before treatment.

For treating solutions, it was decided to use (a) Lignasan† and (b) a mixture of sodium carbonate and sodium bicarbonate. The Lignasan solution was made by dissolving $\frac{1}{2}$ lb. of dry powder in 20 gallons of cold water, and the soda solution by dissolving 14 lb. of washing soda and 6 lb. of bicarbonate of soda in 20 gallons of water (the solution thus being equivalent to 3 per cent. of soda ash and 3 per cent. of soda bicarbonate).

Method of Treatment.—Before treatment, each board was carefully examined for the presence of stain, and when this was found it was marked. Most of the stain found was due to saw marks and handling. Treatment was carried out by completely immersing the boards in the treating solution for at least five seconds. The boards were then allowed to drain for a few minutes and were then placed in their respective stacks. The Lignasan treatments were made with cold solution, but the soda solution was maintained at 140 deg. F.

Erection of Stacks.—The experimental stock was stacked in different ways. Three stacks—one Lignasan treated, one soda treated, and one untreated control—were erected, using a “lap” stack slightly modified from that in use at the factory. The modifications consisted of the

* An example of “lap” stacking is shown in Fig. 1 (top).

† In Australia, Lignasan costs about 60 cents U.S. currency per lb., and treatment would thus probably cost for chemicals alone only about 2d. per 100 super. feet of case stock.

addition of 4-in. foundations and the substitution of $\frac{3}{8}$ -in. square strips at the ends, instead of the factory practice of using case sides for end strips (see Fig. 1 (top)).

Two stacks—one Lignasan treated and one untreated—were erected on 4-in. foundations, each tier of boards being separated by $\frac{1}{4}$ -in. square strips (see Fig. 1 (bottom)).

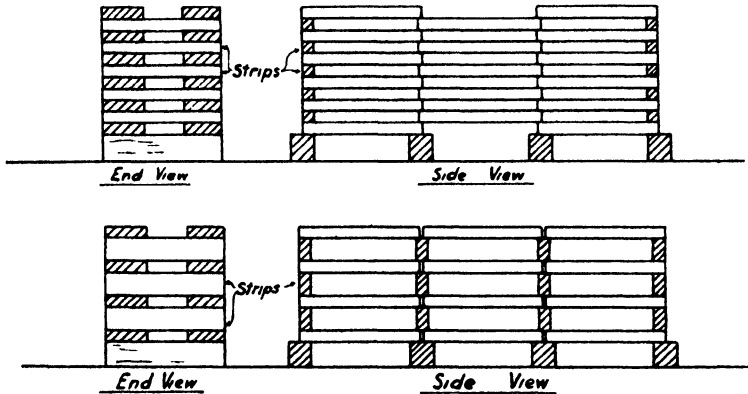


FIG. 1.—(Top)—Diagrammatic sketch of "lap" stack. Strips 3/8" thick. Foundations 4" high.

(Bottom) Diagrammatic sketch of "strip" stack. Strips 3/4" thick. Foundations 4" high.

In both types of stacks a central flue of 7 inches was left. Stacks were three boards long, two boards wide, and were all approximately 4 feet high, and there was a space of 2 feet between stacks. Dummy stacks were erected in order to ensure that the end stacks did not receive comparatively more air circulation than the others, and also to simulate factory conditions more closely.

Period of Test.—Periodical cursory examination of the stacks was made, and it was found that within three weeks blue stain had developed to a considerable extent. Mould growth was apparent in the soda and Lignasan treated stacks at the same time. All stacks were allowed to remain for a period of about nine weeks, when they were demolished and the shooks examined.

Method of Inspection and Recording of Results.—All stacks were demolished in the same way, boards being removed from each tier commencing from the end nearest the wall and working towards the front. In each tier (or approximate tier in the case of "lap" stacking) there were six boards; each board was carefully examined, and where blue stain or surface mould was present an estimate was made of the percentage surface area affected on both the top and bottom of the boards. From the figures so obtained, the total percentage surface area affected was calculated. In some cases, boards containing small percentages of truewood were noted, the blue stain apparently affecting the total sapwood present. The blue stain in such boards was noted as a percentage of the area of the whole board surface. Exact differentiation of sapwood and truewood was difficult, and it did not appear necessary to record such detailed results, the actual difference on the whole being negligible.

The moisture content of four boards in each five tiers was determined electrically (by a Blinker), and the average of these taken as the average for the five tiers.

Results of Test.—In Table 1 the results of the detailed analyses of the untreated and Lignasan treated "lap" stacks are given, and in Table 2 the summarized results of all stacks. The moulds reported are due to the growth of a green-coloured *Penicillium*. The effect of faster drying is shown in the reduced stain or mould development in the top and bottom tiers of the stacks.

Considering the "lap" stacks, it is seen from Table 2 that 71 per cent. of the total surface area of the boards in the control stack was blue stained compared with 40 per cent. in the soda treated and none in the Lignasan treated. With the exception of one board, no mould growth occurred in the untreated stacks, whereas it was common in both the soda and Lignasan treated stacks. In the soda stack, it occurred alone in the top boards, but lower in the stack it was intimately associated with blue stain. The development of mould in the Lignasan stack was about equal in percentage to the blue stain development in the soda treated boards. Soda treatment reduced the total percentage of stain and also the percentage number of boards affected, the latter from 93 to 69.

A study of Tables 1 and 2 and the detailed results not shown indicated that, with increasing depth in the stack, there occurred a greater development of stain and mould which was closely correlated with the average moisture content determined at the time of examination. In the top fifteen tiers of the soda-treated stack only one board was slightly stained, while in the untreated stack 78 boards were stained, although the average moisture contents were very similar. Soda, therefore, retards blue stain development, but only under certain conditions. It is suggested that the value of soda solutions as a stain preventative may be a function of the time; that is, soda treatment will prevent blue stain spores from germinating or developing for a limited time only, corresponding to the period required for the neutralization of the alkali by acids diffusing out from the interior of the timber.

The development of mould growth both on Lignasan and soda treated boards is also probably due to the hydrogen-ion concentrations on the surface of the boards, this being such that it is at, or near, an optimum for their development. Also, it is evident from a comparison of Lignasan and untreated "lap" and "strip" stacks that a high moisture content for a considerable time is more necessary for mould than for blue stain development; the success of Lignasan for preventing both blue stain and mould is definitely associated with the method of stacking and the provision in the surface layers of a drying rate sufficiently fast to reduce the moisture content below the minimum required under the conditions created by the Lignasan solution. The latter solution is definitely alkaline. The pH on the surface of the wood, which is normally acid, is thus increased, and in the case of *P. radiata* it is suggested that the increase in pH produces suitable conditions for mould spore germination and subsequent development. A study of the pH of wood and of the change with time in pH of Lignasan and soda dipped boards, when stacked under conditions retarding drying, would give interesting data, and would probably result in the development of suitable solutions to prevent both mould and blue stain development.

TABLE 1.—VARIATION OF BLUE STAIN, MOULD, AND MOISTURE CONTENT IN UNTREATED AND LIGNASAN-TREATED "LAP" STACKS.

No. of Tiers from Top of Stack.	Blue Stain (as percentage of area).		Mould. (as percentage of area).		Average Moisture Content when Unstacked.	
	Untreated	Treated.	Untreated	Treated.	Untreated.	Treated.
1-5 ..	20	Nil	Nil	0 1	17	17
6-10 ..	55	"	"	0·1	19	18
11-15 ..	81	"	"	1 3	23	18
16-20 ..	72	"	"	28	24	21
21-25 ..	72	"	"	30	>30	25
26-30 ..	61	"	"	53	>30	28
31-35 ..	91	"	"	65	>30	>30
36-40 ..	85	"	"	64	>30	>30
41-45 ..	90	"	"	59	>30	>30
46-50 ..	89	"	"	73	>30	>30
51-55 ..	55	"	"	72	26	>30
56-60 ..	..	..	..	28	..	25
Average ..	71	Nil	Nil	39	30 (approx.)	30 (approx.)

All figures on basis of susceptible boards.

In the untreated stack all susceptible boards were affected with blue stain with the exception of 12 out of 30 in the top five tiers and 9 out of 30 in the bottom five tiers.

In the Lignasan-treated stack all susceptible boards were affected with mould with the exception of 29 out of 30 in the top five tiers, 23 out of 30 in the second five tiers; 23 out of 30 in the third top five tiers; 8 out of 28 in the fourth top five tiers; and 5 out of 12 in the bottom five tiers.

TABLE 2.—SUMMARIZED RESULTS OF EXAMINATION OF TREATED AND UNTREATED STACKS.

Type of Stack.	Treatment.	No. of Boards Susceptible.	Blue Stain (as percentage of area).	Mould (as percentage of area).	No. of Boards Affected.	Per-centage Boards Affected.	Average Moisture Content when Unstacked.
"Lap"	Untreated	310	71	Nil	289	93	30
	Soda ..	336	40	Mould associated with blue stain	231	69	30
	Lignasan	312	Nil	39	224	72	30
"Strip"	Untreated	220	31	Nil	148	67	20
	Lignasan	250	Nil	1·7	37	15	20

The provision of $\frac{3}{4}$ -in. spacing strips reduced the percentage area blue stained from 71 per cent. to 31 per cent., and the number of boards affected from 93 per cent. to 67 per cent. in the untreated stack, and the percentage of mould in the Lignasan stack from 39 per cent. to 1·7 per cent. and the percentage of boards affected from 72 per cent. to 15 per cent. By the provision of foundations at least 12 inches high and the use of 1-in. spacing strips, the trouble from moulding of Lignasan-treated boards would probably be eliminated under the conditions in the factory storage room. The mould in the "strip" Lignasan stack was only comparatively light in development and the degrade of

the affected boards therefore not serious. The provision of foundations and the use of 1-in. spacing strips as suggested above would probably not prevent blue stain development in untreated stacks under the existing storage conditions.

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Footrot in Sheep.

By D. Murnane, B.V.Sc.*

The work, the results of which are given in the article that follows, forms part of the programme of investigations that is being undertaken by the Council's Division of Animal Health under the Australian Pastoral Research Trust—Empire Marketing Board scheme. (See this *Journal*, Vol. 4, August, 1931, p. 133). The author has kindly been accommodated at the Veterinary Research Institute, Parkville, of the University of Melbourne. In addition, some of the pens used by him were erected at the Zoological Gardens, Melbourne, by arrangement with the authorities concerned.—Ed.

1. Introduction.

This disease constitutes a major problem involving much field and laboratory work which has engaged our part time attention for the past two years. From the very nature of the condition, it is obvious that the investigation is one which presents considerable difficulties, the chief of which are the complications caused by the gross bacterial contamination of the lesions. It is of considerable economic importance, not on account of high mortality in affected flocks, but because of the loss of condition of affected animals and the cost of constant treatment. In addition, its existence in a flock takes shillings per head off the sale value.

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Footrot is an acute, sub-acute, or chronic disease affecting the feet of sheep and occasionally cattle. It occurs in most countries of the world, and has been known for very many years, being described in Europe as early as 1791. In Australia, it is more prevalent in certain districts than in others, and often assumes epizootic proportions.

Predisposing Factors.—Certain conditions such as overgrown hooves, wet or damp pastures, and heavy growth of pasture (particularly clovers) have been noted to favour the development of footrot, but none of these can be credited with causing the disease. It is a generally accepted fact that the finer-woolled sheep are more susceptible than the coarser breeds, but it is doubtful if any breed is resistant.

Types.—The clinical picture of footrot is well known to sheep-owners in affected districts. We recognize two more or less distinct types—(a) the ordinary “sub-acute” form which frequently passes to a chronic state; and (b) the less common “acute” or “malignant” type.

Symptoms.—In the first-mentioned form, the infection commences with a reddening of the skin between the digits, accompanied by a hot condition of the affected foot—due to the inflammatory process which is taking place. This phase is frequently referred to by sheep-owners as the “scald stage,” and is usually accompanied by lameness. As yet, there is no visible break in the skin. Later, there is some swelling of the affected tissues and an oozing of clear serous fluid. The area becomes quite moist and develops a characteristic and unmistakable offensive odour. Subsequently, the skin breaks down and pus forms. The horny structures become under-run with pus, and as the vascular soft structures (sensitive laminae) beneath the horn are attacked and digested, the soles and even the walls are shed. When only the sole is shed, the wall tends to spread and turn outwards and upwards, leaving the sensitive structures exposed and obviously causing extreme lameness to the extent of forcing the animal to move about on its “knees.” This state may be reached in the comparatively short time of two weeks, but usually takes longer. The lesion may progress slowly or may remain at a standstill (neither improving nor becoming worse) for months. This constitutes what we term the “chronic” state.

Throughout the progress of the disease, the affected animal usually loses weight considerably, partly on account of the pain suffered, partly on account of the inability to move about and obtain sufficient food, and doubtless on account of considerable toxic absorption from the foul lesion.

Occasionally, when making post-mortem examinations on footrot cases which have died, we have found multiple abscess formation in the liver, lungs, and spleen, and it seems likely that these originated from the foot lesion. Usually, however, the lesions are confined to the feet, below the coronet.

The “acute” or “malignant” type, on the other hand, runs a somewhat different course. The lesion seems to commence either in the pastern or in the fetlock joint above the foot, and for a time remains localized in this region. There is considerable swelling of the affected joint with much pain. The tendons and ligaments in the vicinity are

the structures which are particularly attacked. They are rapidly digested, often resulting in luxation of the extremity. Sinuses usually form, and there is a foul discharge, or the pus burrows downward and the foot itself becomes involved. The animal being forced to move about on its "knees," it frequently develops lesions in the knee joints and in the region of the sternum ("brisket") through inoculation of abrasions by contact with discharging lesions in the lower joints. This type of footrot generally runs a more rapid course and is more severe, not infrequently terminating in the death of the animal. (The disease in cattle commonly resembles this "malignant" form in that the tendons and ligamentous structures are involved, but it seems to clear up more readily than in sheep.)

Differential Diagnosis.—There are few diseases of the feet of sheep which may be mistaken for footrot, particularly in Australia, where, fortunately, foot and mouth disease does not exist, but, even in countries where it is prevalent, the differentiation should not be difficult when the disease has progressed past the initial stage.

There is, however, an abnormal condition of the foot not infrequently encountered in sheep running on wet or swampy country which closely resembles the early stage of footrot, and with which it may easily be confused. There is maceration, erosion, and even suppuration of the interdigital tissues accompanied by marked lameness. This condition readily yields to treatment, and in fact may even clear up spontaneously, especially if affected animals are removed to dry surroundings. It is often referred to by farmers as the "non-infectious type."

The writer is of the opinion that both types are infectious, and that both originate in the same manner (i.e., by infection of abrasions of the skin of the foot), the progress of the condition and the ultimate lesions depending entirely on the type and virulence of the invading organism.

Natural Infection.—There is little doubt that the disease is infectious. The nature of the lesion and the rapidity with which the trouble spreads through a flock when introduced under favorable conditions seems to adequately support this view. It is quite common to find owners who state that they never experienced footrot prior to the purchase of a few infected animals from which the disease rapidly spread to their flocks. That infection may take place quite rapidly is demonstrated by the fact that young lambs of affected ewes have been known to contract the disease within two or three weeks of birth.

Etiology.—The determination of the causal organism has presented the greatest difficulty. In the case of an infectious disease affecting an internal organ, the isolation of the infecting germ is usually a simple bacteriological procedure, as the organism is as a rule uncontaminated by others. In the case of footrot, we have an external lesion in contact with soil, faeces, &c., and consequently contaminated with hundreds of organisms—pathogenic and non-pathogenic. This makes the task of determining the initial causal organism infinitely more difficult. Certain workers in France have attributed footrot to infection with the tissue parasite *Treponema podovis* which they claim to be present in enormous numbers in the lesions. This view has been supported by one or more workers in America, although as far as we are aware the disease has not been produced experimentally by inoculation with this organism, nor has the organism even been cultivated.

Other American workers (notably Mohler and Washburn) are equally firm in the opinion that the causal organism is *Bacillus necrophorus*.

After microscopical examination of a large number of smears and preparations from affected feet, we strongly incline to the latter view. We have found that in practically 100. per cent. of cases examined, *B. necrophorus* is present, while in only two or three cases* have we seen organisms resembling the *Treponema* mentioned, and, further, it is very questionable whether these were of a pathogenic nature. However, at present we refrain from stating that the *Treponema* is of no significance. Whether we are justified in incriminating *B. necrophorus* as the primary causal agent of footrot may be open to doubt. Owing to the ubiquitous character of the organism, it may be that it is a common secondary invader. But, whether it be primary or secondary, the fact remains that the chief lesions seen in the vast majority of cases of footrot (neglecting the mild non-progressive type mentioned earlier) are definitely those of necrosis associated with the presence of *B. necrophorus*.

B. necrophorus is not credited with penetrating unbroken or healthy skin, and we believe that in the case of footrot this probably holds true, the tissues of the foot being first injured or abraded by some other agent, either traumatic, climatic, parasitic, or bacterial, thus permitting the entry of the organism.

The Organism.—As part of the Australian investigations of footrot, *B. necrophorus* has been studied in detail by Messrs. H. R. Carne and W. I. Beveridge, at the F. D. McMaster Laboratory in Sydney, and has been described very fully by the latter in a recent paper which will shortly be published. The more general characters may be found in any modern bacteriological textbook. Suffice it to say that the germ is a filamentous, non-sporing, highly pathogenic anaerobe, and is regarded as a common inhabitant of the normal intestine of pigs (and probably ruminants and horses), of faeces, and of soil contaminated with faeces.

Pathogenicity.—The number of disease conditions with which *B. necrophorus* is associated is surprising. It is capable of producing lesions in various parts of the body in most of the lower animals and in man. Rabbits and mice are particularly susceptible, and are therefore commonly used for the purpose of isolating the organism from natural footrot lesions.

Emulsions of scrapings from the deeper parts of the lesion (at the junction of the diseased and healthy tissues) are injected subcutaneously or intramuscularly. A necrotic lesion results and extends rapidly as the organism multiplies and attacks adjacent healthy tissue. Death of the inoculated animal usually takes place within 10 days. The extension of the necrotic area is so rapid that most of the original contaminating organisms (many of which are non-pathogenic) are left behind at or near the site of inoculation. Necrotic material from the periphery of this lesion is then taken and injected into a second experimental animal.

* Two of these cases were received from the Division of Animal Nutrition, Adelaide, through the kindness of the Chief and Mr. Lincs.

After two or three such passages it is usually possible to recover *B. necrophorus* in pure culture, or so slightly contaminated that it can be isolated by cultural methods such as growth in deep solid media. Some workers inject the contaminated material intravenously into rabbits, in which case necrotic lesions develop in the liver. We prefer the subcutaneous or intramuscular method.

Pathology.—In footrot, the natural lesion seems to be essentially of a necrotic nature. There appears to be progressive death of the sensitive structures of the foot, followed, of course, by bacterial liquefaction. From the position of the lesion, this is to be expected, as there is every opportunity for heavy contamination from the soil and faeces. But in the deeper regions of the lesion, near the junction of healthy and affected tissues, *B. necrophorus* appears to be the predominating organism, and in fact may often be seen in almost pure culture.

2. Experimental.

A large amount of experimental work with sheep has been carried out, of which a general outline of the tests made, with results, is given below.

(i) *Tests to prove the infectious nature of the condition.*

(a) A series of tests was set up whereby groups of clean sheep were placed in close contact with groups of chronic natural cases in small pens, where they remained for a period of four months. Control groups of equal size were held in adjoining pens under similar conditions, except that they were not in contact with affected animals. As this experiment was carried out during the dry months, the soil was kept moist by daily irrigation. *Result:* No footrot developed in the contacts (or in controls).

(b) The above tests were repeated during the winter months, using the same sheep and the same pens. *Result:* All contacts developed footrot. Controls remained free. The experiment was repeated, using different pens. *Result:* Contacts developed footrot. Controls free.

(ii) *Effect of maceration alone.*

(a) Several groups of clean sheep were kept standing in water for approximately 8 hours daily for a period of several weeks. *Result:* No footrot.

(b) Numbers of sheep were fitted with canvas boots ("footrot boots") which were daily filled with water for a period of several weeks. *Result:* No footrot.

(iii) *Direct inoculation with pus.*

Numerous groups of animals have been lightly scarified between the digits and smeared with pus from natural cases. Early in the investigation, these tests were attended by negative results. Later experiments on similar lines, however, have given positive results in the majority of cases, particularly when the animals were kept under wet conditions.

(iv) *Inoculation with filtrates of material from natural lesions.*

In order to determine whether or not a filtrable virus is associated with the condition, the filtrate from an emulsion of diseased material which had passed through a bacteria proof (L2) filter was smeared on scarified areas on the feet of several groups of clean sheep at different times. *Results:* Negative in all cases.

(v) *Inoculation with pure cultures of individual organisms isolated from natural lesions.*

A number of different anaerobes were isolated and cultured. Separate sheep were scarified and inoculated with each organism, *Results:* Negative.

(vi) *Inoculation with cultures of B. necrophorus.*

Numerous groups have been lightly scarified and inoculated with pure cultures of this organism. *Results:* Most of the earlier tests were negative. Later experiments gave inconsistent results. More recent tests have given positive results in the majority of cases.

(vii) *Inoculation with culture of B. necrophorus isolated from natural case of bovine footrot.*

Two sheep and one calf were scarified and smeared with culture. *Results:* Definite and typical lesions developed in all three animals.

(viii) *Test to ascertain whether early cases of footrot will progress if the subjects are removed to thoroughly dry surroundings.*

Several very early natural cases were brought from the country and placed in a perfectly dry pen at the laboratory, where they were retained for 6 weeks. Footrot progressed to an extremely advanced stage, the hooves being shed in two cases.

3. Treatment.

The first step in the elaboration of any curative or preventive measures is to establish the cause, and most of our effort has been spent in this direction. On account of the numerous requests from sheep-owners for advice as to treatment, it was felt that something might be done in the meantime, even though such treatment were more or less empirical and only partially successful. Several methods of treatment and numerous proprietary preparations have been tested. As a result, we offer the following recommendations, which, we hope, may be improved upon as our work progresses.

Preventive.—On properties where footrot is known to occur, the feet of all sheep should receive careful attention and should be closely watched. It is unnecessary to stress the point that prevention is better than cure and less costly. Overgrown feet should be trimmed, and, if infection is suspected, all animals should be passed through a suitable footbath once a week. Where the country is wet or where pasture is rich and heavy, beneficial results have been reported from the practice of providing small plowed areas here and there which form comparatively dry "camps" for the animals. (It may be noted how affected sheep themselves frequently seek dry spots such as banks of dams, on which to camp.)

Curative.—The first essential is prompt action. Only too often the first few lame sheep in a flock are neglected until a large number have become affected. At the first sign of trouble, the flock should be yarded. The visibly affected animals should be isolated, while the remainder should be passed through a footbath with the object of prevention.

All affected animals should be kept isolated in a small convenient paddock and receive the following intensive treatment:—The affected feet should be thoroughly trimmed; all loose, under-run or separated horn should be removed; and the animals should then receive prolonged footbath treatment. On a property where footrot is prevalent, a well constructed and adequate footbath is an absolute necessity. The owner who tries to cope with footrot without a footbath is usually wasting his time and money. A concrete bath, in the form of either a race or a pen capable of accommodating 50 sheep or more according to the size of the flock, should be constructed. The solution to be used is a matter of choice. Numerous proprietary preparations are available, in respect to the efficacy of many of which very extravagant claims are made by the manufacturers. However, it can be stated that most of these products will give results if used in the manner about to be described, as will agents such as copper sulphate (bluestone), formalin, and "Monsol." The strengths recommended are—

Copper sulphate—5% solution (= 1 in 20, or $\frac{1}{2}$ lb. to the gallon of water).

Formalin—2% solution.

Monsol—1% solution.

Having pared the affected feet, the animals are placed in the footbath solution. They are not simply walked through the bath and out at the other end as is the common practice, but are held in the solution for at least one hour. The reason for this is obvious. It allows the antiseptic to penetrate the sinuses and pockets of pus in the affected foot. A mere walk through the bath does nothing more than wash the exposed surfaces, and no matter how efficient an antiseptic may be, it clearly cannot be effective if it is not permitted to come in contact with the organisms against which it is being used. While it may suffice as a preventive, unsatisfactory results must always follow mere walking of animals through a footbath as a curative method.

Therefore, we stress the point that the length of time the affected feet are allowed to remain in the footbath is a most important factor. It is for this reason that we have recommended a footbath of large capacity. In the case of affected sheep, the treatment should be repeated several times at two-day intervals. We have been able to demonstrate that extremely advanced (chronic) cases readily recover under this intensive treatment.

Similar results can be obtained by the use of "footrot boots" which are on the market. The canvas "boot," filled with an antiseptic solution, is placed on the affected limb for a period of several hours. Where a large number of animals are to be treated, the use of a footbath would be preferred by most owners.

Bluestone is a cheap and effective solution, but it has a disadvantage in that it stains wool. Formalin in 2 per cent. solution is even cheaper than bluestone 5 per cent. It is quite effective, and does not stain wool.

In addition, it has a desirable hardening effect on the affected feet. Where possible, sheep should be held in a shed or on a dry floor for several hours after footbath treatment. When animals are kept for a prolonged period in a footbath, the solution becomes fouled with droppings which float and which should be skimmed off after use each time. This adds to the length of life of the solution. We find that the same solution can be used 4 or 5 times at two-day intervals before having to be discarded.

The question of local (external) dressings applied after trimming the affected feet has received consideration. Although the antiseptics are usually employed in more concentrated form in these cases, we are of the opinion that such dressings cannot be relied upon to give satisfactory results, on account of the impossibility of getting the antiseptic into all small pockets and sinuses. From the numerous preparations used, one of the following may be selected:—

1. Picric acid—4 ounces .. } Apply with a brush.
Methylated spirit—1 gallon
2. Powdered resin—2½ lb., dissolved in 1 gallon of turpentine, then add "Monsol"—½ pint. Shake or stir vigorously until a uniform mixture is obtained. Apply with a brush.

It will be found that, as it dries, this second mixture forms an adhesive coating on the foot, thereby holding the antiseptic in contact longer than would otherwise be the case.

3. Formalin—1 part, glycerine—9 parts.
4. A mixture recommended by the Victorian Department of Agriculture, made as follows:—
Stir into 1 quart of warm Stockholm tar 2 ounces of finely ground bluestone, and add 1 tablespoonful of lysol or "Monsol." Apply with a brush.

The use of powerful irritants such as pure carbolic or hydrochloric acid, pure formalin, &c., is condemned on account of resulting destruction of healthy tissue.

The "malignant" or joint type of infection is much more difficult to deal with. It is best treated by surgical methods, i.e., opening the "pocket" of pus with a clean sharp knife, removing as much as possible of the necrotic tissue, and syringing out the cavity with an antiseptic solution such as hydrogen peroxide 1 part, water 3 parts. The pus "pocket" may then be packed with the following antiseptic powder:—Boracic acid and chlorinated lime (bleaching powder), equal parts.

In this type of infection, the destruction of tendons and ligaments is frequently so extensive that permanent deformity of the joint remains.

The treatment for cattle is similar to that recommended for the "malignant" type in sheep, and could be combined with footbath methods.

Further work is in progress, by which it is hoped to confirm our tentative conclusions and to elaborate more effective curative and preventive methods. The question of a preventive vaccine is being kept in view, although the nature of the disease probably does not offer great possibilities in this direction.

Downy Mildew (Blue Mould) of Tobacco.

I. The Influence of Over-Wintered Plants, II. Wild Hosts, and III. Spraying.

By A. V. Hill, B.Agr.Sc.,* and H. R. Angell, Ph.D.†

Summary.

1. Over-wintering diseased tobacco plants were shown by microscopical examination and field observation to be sources of seedbed infection by downy mildew.

2. *N. glauca*, systemically infected with downy mildew, was found growing in close proximity to seedbeds even in districts remote from tobacco-growing areas.

3. Spraying seedlings with 2-2-40 Bordeaux mixture did not prevent the occurrence and spread of downy mildew when the disease was epidemic in neighbouring seedbeds.

4. Downy mildew did not occur early in isolated seedbeds, nor was it destructive where the plants were grown under relatively dry atmospheric and soil conditions.

I. Over-wintered Plants.

Introduction.—The widespread occurrence of downy mildew in the tobacco-growing districts of New South Wales and Victoria during the autumn of 1932 led to the expectation that many diseased plants would survive the winter months and produce new growth bearing conidia to initiate and spread the disease in the spring. Since but little definite experimental work was previously done with the object of showing to what extent over-wintered diseased plants might be the source of outbreaks in seedbeds in commercial tobacco-growing areas, an attempt was made in 1932 to determine their importance under those conditions.

On account of the absence of wild hosts of the downy mildew fungus and because of its relative nearness to the research laboratories at Canberra, the Tumut district was selected for the work.

Importance of Over-Wintered Plants.—Diseased plants growing in the experimental plots at Canberra during 1930 were examined from time to time, and areas bearing conidia were found on them in autumn. Microscopic examination at that time showed that mycelium was present in the leaves, stems, and roots. The aerial portions of the plants were, as usual, killed by frosts during the winter, but the basal portions remained alive, and the dormant underground buds began growing during the early part of September. Some of the shoots were removed before they reached the level of the surface of the soil, and, after being sectioned and stained, were examined under the microscope. The mycelium of a coenocytic fungus was found growing intercellularly in the tissues of the young shoot. In the following month,

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other shoots on the same plants, which were allowed to grow above ground, showed the characteristic symptoms of the disease. It was evident that downy mildew survived the winter as mycelium in the plants, and that the disease on the new spring growth arose from it and not from external sources.

The production of conidia on over-wintered plants in farmers' fields was repeatedly observed during the past four years. The importance of such plants as a source of infection of seedlings in spring was recorded by Adam(1) and the writers(2).

Further evidence presented in this paper serves to emphasize the necessity for eradication and destruction of tobacco plants immediately harvesting is completed.

Cultural Practice in Relation to Over-Wintering Plants.—The bulk of tobacco grown in New South Wales and Victoria at present is produced on river flats which are subject to flooding during the winter months. If such fields are cultivated during autumn and winter, the occurrence of floods, usual in spring, may result in a considerable amount of soil erosion. Tobacco fields, therefore, are often left uncultivated until a few weeks before they are required for the following season's crop. Under such conditions, the majority of the plants from which the leaf has been harvested remain alive during the winter months of June, July, and August. Some of the plants are killed by flood waters, but others remain alive and may even produce leaves throughout the winter, the young shoots being protected from slight frosts by the old or dry leaves overhanging them. In most cases, however, the aerial portions of the plants are killed by frosts, but the crown and roots remain dormant until the following spring, when new shoots are produced. Fields of such plants are commonly seen in tobacco-growing areas during September, October, and November.

As seedbeds are sown in July, August, and September, the main sowings being completed in August, and transplanting is done during November and December, the danger of infection from over-wintered plants is evident.

According to Dickson(5), flood waters in New South Wales and Victoria during the winter of 1931 covered practically all the land planted to tobacco in the previous season, the over-wintered plants being killed thereby. The absence of such plants, the use of clean seed, and a comparatively unfavorable season for downy mildew, resulted in late development of the disease instead of early in the season as is usual. Consequently, a plentiful supply of seedlings was available for the 1931-32 season.

As the disease is more or less severe each year in the areas where the main crops are grown, Victorian growers endeavour to sow seedbeds in dry localities far removed from such districts. The extension of commercial tobacco production to the drier seedbed areas during the 1931-32 season resulted in the establishment there of over-wintering plants.

During the spring of 1932, it was consequently difficult to find an area suitable for seedbeds that was also remote from over-wintering plants and accompanying tobacco diseases prevalent during the previous season. Under the circumstances, the seedlings were likely to be

attacked by diseases which were present on plants in the district. A survey of the areas concerned showed that this factor was one of those responsible for outbreaks of downy mildew during the 1932-33 season.

Observations in the Tumut area in 1932.—While conducting spraying experiments in the Tumut district during the spring of 1932, old tobacco stalks were located, and observations made on the dates of appearance of the disease on them and subsequently in the nearby seedbeds.

In this area, tobacco is grown on river flats in narrow valleys surrounded by mountainous country which isolates the district from other agricultural areas. While on visits to the fields in the autumn of 1932, it was observed that plants in many of them were seriously affected with downy mildew. On 16th August, another examination showed that many plants from the previous season were still alive and producing new growth. In one field, the lower surfaces of some young leaves measuring 5 inches in length, were covered with conidiophores and conidia of the downy mildew organism. Seedbeds were actually being sown in the district at that time. Three weeks later, over-wintering diseased plants were still present in the fields, and at the same time, seedlings were developing in the seedbeds throughout the district.

As the conidia were seen on the leaves of the over-wintered plants as early as 16th August, early infection in seedbeds was expected. On 18th October, other over-wintered plants with a profuse development of conidia were found, and within 300 yards was a seedbed that had downy mildew. In the seedbed, the disease was not on scattered individuals but on groups of plants. Seedlings from the same lot of seed, sown half a mile further from the over-wintered plants than those just mentioned, did not become diseased until 14th November, i.e. 26 days later. On 30th October, the disease also attacked other seedlings nearer the over-wintered plants but in the opposite direction.

An attempt was made to trace the spread of the disease throughout the district, but owing to the disinclination of many farmers to admit so early in the season that it was then present, it was impossible to carry out the plan. Infection was reported from a number of seedbeds two weeks after the above-mentioned outbreak of 18th October.

The experimental seedbeds sown during the first week of September were situated at intervals of approximately $\frac{1}{4}$ mile from over-wintered diseased plants. On 29th October, disease was observed in the nearest one $\frac{1}{4}$ mile away, on 9th November in another $\frac{3}{4}$ mile away, but the seedlings at a distance of 1 mile remained healthy until 28th November. This may be taken as indicating that the disease spread in ever-widening circles from the over-wintered plants and from the earlier attacked seedbeds, the number of conidia in the meantime increasing from the relatively few thousands on the original plants to countless millions produced in each seedbed every day. Those seedlings farthest removed remained healthy for the longest time, provided the organism was not introduced into the seedbed on the clothes and implements of workmen.

The association of over-wintered diseased plants with the initial outbreak and subsequent spread of downy mildew to seedbeds definitely shows the importance of such plants as sources of infection.

2. Wild Hosts.

Introduction.—In a previous publication(2), the writers briefly discussed the host plants and the history and geographic distribution of the downy mildew fungus. It was shown by inoculation experiments that about twenty, and therefore probably all, species of the genus *Nicotiana* including *N. glauca* Graham and *N. suaveolens* Lehm., which are widespread in Australia, are susceptible to downy mildew. The importance of these plants as carriers of the disease is more than is at present realized by tobacco growers. Both species probably occur in all the States of the Commonwealth.

N. glauca—*Tree Tobacco.*—The comparative drought resistance of *N. glauca* was perhaps one of the reasons for its use as a hedge plant and as an ornamental shrub in gardens many years ago. Later, it escaped from cultivation and became established in many localities. It now occurs near Charters Towers, Queensland, is fairly common in dry districts north of Adelaide, South Australia, and has been observed by the writers at Tamworth in the north and Deniliquin in the south of New South Wales, in the Murray River Valley from Corowa to Cobram, at Shepparton in the Goulburn Valley, and also near Sea Lake and Melbourne, Victoria. In many cases it occupies comparatively small areas near townships, but in other localities it is spread over large areas, and it would therefore be difficult, if not impracticable, to eradicate it. Because *N. glauca* is considered a poisonous plant, it has been declared a noxious weed in many shires of New South Wales(6). The plant may therefore be a source of loss both to tobacco growers and stock-owners. (Plate 2).*

N. suaveolens.—Another species of wild tobacco, *N. suaveolens*, is regarded by some as native to Australia. Bailey(3) records three varieties, *longiflora*, *parviflora*, and *Debneyi* in Queensland. Black(4) records *N. suaveolens* and *N. excelsior* in various localities in South Australia. McAlpine(7) observed downy mildew on *N. suaveolens* in Victoria, and this plant was reported in 1932 by Pittman(8) as a host of downy mildew in Western Australia. According to Stewart(10), it caused the death of some bullocks near Narrabri, New South Wales, in 1908, and that it was poisonous to sheep was also shown by Seddon and McGrath(9). It has not been reported from Tasmania. This plant, therefore, like *N. glauca*, is both poisonous to stock and a host for downy mildew of tobacco. Its occurrence in northern New South Wales may possibly be correlated with the appearance of downy mildew in tobacco, for it was in this area that the disease is commonly believed to have been first seen in Australia.

Both *N. glauca* and *N. suaveolens* tend to be restricted to localities having an average rainfall of about 25 inches or less. At Deniliquin and Cobram, in 1932, the former was severely attacked by downy mildew, the young shoots being in some cases killed by the disease. Conidiophores and conidia were seen on the affected leaves. Nearby tobacco seedbeds were seriously attacked. As this plant is a perennial shrub, the mycelium of the fungus is able to persist from year to year in the stems, from which it grows into the leaves and produces conidia by which the disease is spread to tobacco seedbeds.

* See Plates facing page 308.

* It is therefore essential for growers to ensure that neither *N. suaveolens* nor *N. glauca* occurs near the site of the seedbed. If eradication is impracticable, another site should be selected in an area where neither wild hosts nor over-wintering plants occur.

3. Spraying Experiments.

(i) *Introduction*.—Bordeaux mixture is the fungicide most extensively used for the control of downy mildews other than that on tobacco. This spray material gives a useful measure of control of some diseases, if the foliage can be readily wetted by it, but as some of the leaves of tobacco are close to, and parallel with, the ground, wetting their lower surfaces with spray is a difficult matter. Since infection of tobacco by downy mildew takes place at any stage of growth, and on any part of the surface of the leaf, it is necessary from shortly after germination to cover both the upper and lower leaf surfaces with spray.

Nevertheless, the spraying of isolated seedbeds may possibly be of some value, as the number of conidia present in the atmosphere around remote seedbeds would be fewer, and the plants would be given partial protection by the fungicide.

The spraying experiments conducted at Tumut and Canberra by the writers(2) during 1931 did not give promise of an effective means of control of downy mildew, but more experimental work was considered necessary before recommendations were made. As previous experiments showed that repeated applications of 4-4-40 Bordeaux were harmful to seedlings, a 2-2-40 mixture was used.

(ii) *Tumut Experiments*.—At Tumut, in 1932, a series of five seedbeds, each approximately 20 square yards in area, was set out at intervals of about $\frac{1}{3}$ mile in a section comparatively isolated from other seedbeds. Seed of the variety Warne was sown on 8th September. The seedbeds were covered with butter muslin until the seedlings were established, about 4-5 weeks after sowing. Spraying with 2-2-40 Bordeaux mixture was begun on 15th October when the plants were three weeks old, and was continued at five-day intervals, one-half of the seedbed area in each case being sprayed and the other half left as a control.

On 17th October, downy mildew was first reported from a farmer's seedbed about $\frac{1}{3}$ mile distant from experimental seedbed No. 1. Several diseased plants were present in the unsprayed section of seedbed No. 1 on 29th October, and 16 days later the disease had spread throughout both sections. At the time the first infection was observed, the leaves of the largest seedlings were $\frac{1}{2}$ inch in diameter. Infection became general throughout both the unsprayed and sprayed seedlings before the plants were fit for transplanting. The protection afforded by the spray was therefore of no practical value.

Diseased plants were first seen on 9th November in the unsprayed section of seedbed No. 2, which was approximately $\frac{1}{3}$ mile distant from seedbed No. 1 and $\frac{2}{3}$ mile from over-wintered diseased plants. In the sprayed section, the disease was seen 15 days later. During the interval, one lot of plants suitable for transplanting was taken from the sprayed

bed. In this case, therefore, the spray gave useful protection for 1 to 2 weeks. More effective protection might have been given by spraying all the beds.

Seedbed No. 3, situated 1 mile from the over-wintered diseased plants, was in a sunny position on well-drained, sandy soil, such a location being deemed comparatively unfavorable to the onset and spread of downy mildew. On 28th November, diseased plants were found in both the sprayed and unsprayed sections of this seedbed. Previous to this date, two lots of plants were taken for transplanting. The disease spread comparatively slowly and was less severe in the sprayed section.

Downy mildew was also found in seedbeds 4 and 5 on 28th November, the disease appearing in sprayed and unsprayed sections of seedbed 4, and in the unsprayed section of seedbed 5. It was found in the sprayed section of the latter seedbed, 9 days later. Seedlings were obtained from both these seedbeds before downy mildew occurred, and an extra lot was obtained from the sprayed section of seedbed 5.

The location of the seedbeds in relation to over-wintered diseased plants is shown on the accompanying plan (Fig. 1), while the occurrence of downy mildew in the seedbeds is shown in Table I.

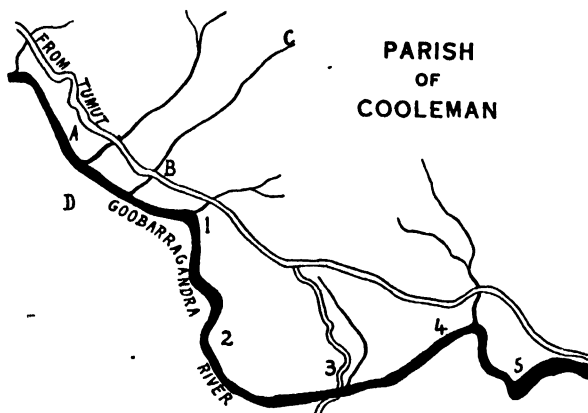


FIG. 1.—Showing the location of experimental seedbeds, referred to in the text as Nos. 1-5, in relation to over-wintered diseased plants at A. The earliest reported outbreak of downy mildew in the district was in seedbeds at B., and the site of other seedlings, which remained healthy for a longer period, is shown at C. The latter were from the same seed as was sown at B. The seedbeds at D. were also diseased.

Discussion.—In these experiments, the protection afforded seedlings by Bordeaux mixture varied from 0 to 16 days. As the disease attacked some of the seedlings when they were too small for transplanting, the protection of 16 days was, in this instance, of no practical value, but from the sprayed sections of two other groups of seedbeds one extra lot of seedlings was obtained.

In each group, the unsprayed section was adjacent to the sprayed. Therefore, as soon as the disease attacked either section, sufficient conidia were produced to infect all plants in the seedbed, in spite of the fungicide. On account of the mode and rapidity of growth of seedlings, complete protection by sprays or dusts is very difficult, if not impossible, to obtain in practice.

TABLE I.—OCCURRENCE OF DOWNY MILDEW IN SPRAYED AND UNSPRAYED SEEDBEDS AT TUMUT, 1932.

Seedbed Number.	Distance from Over-wintered Plants showing Disease on 18th October.	Occurrence of Disease in Seedbeds.		Protection by Spraying.	Usefulness of Spray.
		Unsprayed.	Sprayed.		
1	$\frac{1}{2}$ mile	29 Oct.	15 Nov.	16 days	None. Seedlings too small for use as transplants.
2	$\frac{2}{3}$ mile	9 Nov.	24 Nov.	15 days	One picking of plants from sprayed seedbed
3	1 mile	28 Nov.	28 Nov.	None	None
4	$1\frac{1}{2}$ miles	28 Nov.	28 Nov.	None	None
5	2 miles	28 Nov.	7 Dec.	9 days	One extra picking of plants from sprayed bed

The seedbeds were attacked in the order of their distance from the original focus of infection, the earliest attacked being those nearest the diseased, over-wintered plants. It appears, therefore, that isolation from sources of infection was of more practical value than the use of the fungicide. Many instances have been brought to our notice of isolated seedbeds that remained disease-free for long periods, sometimes until after the transplanting season was over. In other instances, they were infected by persons who had previously been handling diseased plants. The importance of man as an agent in introducing the disease was further emphasized by the writers' experience at Canberra, where research work on downy mildew was in progress under glasshouse and field conditions. On three successive occasions, the disease was purposely introduced, and after each general infection, all diseased seedlings were destroyed and fresh sowings made after intervals of several weeks. Unless the disease was deliberately introduced by us, seedlings remained healthy, even though conditions were most favorable for its development. It was

necessary in every case to obtain diseased material from tobacco-growing districts in order to infect the first plants in the glasshouse or field. From these infected plants, the disease spread to all others in the glasshouse. After the disease was introduced, the only method of eradicating it was by the destruction of all tobacco seedlings and plants.

In tobacco-growing areas, eradication of diseased tobacco seedlings is impracticable, because that procedure may involve the loss of the year's crop, but eradication of unused seedlings and of plants after harvesting involves no loss, while the time and money spent in doing it is an investment that will minimize loss in the following seasons.

The use of clean seed, and freedom from diseased over-wintering plants throughout an entire district, would very materially assist in the production of healthy seedlings throughout the season, or, if the disease appeared, its chances of causing serious loss would be lessened by its delayed appearance.

(iii) *Canberra Experiments.*—Four seedbeds, each 18 square yards in area, separated by distances of approximately 25 yards, were sown in the experimental plots of the Council for Scientific and Industrial Research at Canberra on 22nd August. Spraying with 2-2-40 Bordeaux mixture was commenced on 21st October, and was continued at five-day intervals on three of the seedbeds. The other seedbed served as a control. Towards the end of October, it was found necessary to introduce downy mildew from the Tumut district, situated about 70-80 miles away in a westerly direction. Seedlings in the glasshouse, about 100 yards distant from the seedbeds, were inoculated with the introduced material, and became infected. The disease spread rapidly in the glasshouse, and from the glasshouse to the unsprayed bed, in which it was seen on 22nd November. In the two nearby sprayed seedbeds, it appeared on 2nd December, and in the most distant sprayed seedbed on 12th December. The experiment was then discontinued.

On account of the presumably unfavorable climatic conditions at the time, the disease did not spread rapidly even among the unsprayed seedlings, and only comparatively few seedlings in the sprayed beds were attacked.

Discussion.—In experimental work during the past four years it has been found that climatic conditions at Canberra (high temperature, low rainfall and humidity) are comparatively unfavorable to downy mildew during the late spring and summer months. Control measures based on experiments in this or other areas with a similar climate may not be effective when applied in districts where the climate is different and the disease is in consequence epidemic every year.

Two sprayed seedbeds remained free of disease for 10 days, and the third seedbed for 20 days after the unsprayed seedlings were attacked, but the disease did not spread very rapidly either in the sprayed or unsprayed seedbeds. On the other hand, the disease was epidemic in similar seedbeds at Tumut at about the same time. Climatic factors, therefore, were probably more important than the spray in the control of the disease. In Tumut, seedbeds on a well-drained sandy soil in a sunny position were less seriously attacked.

In commercial tobacco areas, therefore, more attention should be given to choosing a seedbed site that is well drained, in a sunny position, and if possible on sloping land, to allow of adequate air drainage. These precautions will tend to delay the attack and rapid, destructive spread of the disease.

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Addendum.

An examination of the tobacco-growing districts and seedbed areas of southern New South Wales and Victoria early in September of this year (1933) showed that conidia were being produced in abundance on over-wintered plants which were present wherever tobacco was grown during the previous season. In many cases, such plants were found within a few yards of seedbeds in which the seedlings were still young.

Foot and Root Rots of Wheat in Australia.

The Influence of the Combined Action of *Fusarium culmorum* (W.G. Sm.) Sacc. and *Urocystis tritici* Koern. on the Occurrence of Seedling Blight.

By W. L. Geach, B.Sc.*

Summary.

1. During the past three seasons, an unusual amount of seedling blight was observed under glasshouse conditions among plants grown in unsterilized soil from grain inoculated with spores of *Urocystis tritici*. Isolations from the affected plants yielded *Fusarium* spp., generally *F. culmorum*, and *Helminthosporium sativum*, or both.

2. In an adjoining glasshouse, plants grown from grain inoculated with *F. culmorum*, or in soil inoculated with *H. sativum*, were not so consistently nor severely attacked by seedling blight as those in the flag smut experiments referred to above.

3. When grain was inoculated with a mixture of spores of *U. tritici* and conidia of *F. culmorum*, a greater amount of seedling blight occurred than among plants from grain inoculated with either of these organisms alone, whether in the field or in pots containing sterilized or unsterilized soil. In contrast with this, a comparatively small amount of seedling blight occurred under the same environmental conditions among plants from grain inoculated with only *F. culmorum* or *U. tritici*.

4. Under field conditions, varieties highly resistant to *U. tritici* were only comparatively resistant to seedling blight due to the combined attack of the two organisms.

5. The two organisms acting together under ordinary field conditions are partly responsible for poor stands.

6. It is possible that *U. tritici* or other smuts, in combination with other foot rot pathogens, may yield results similar in general effect to those reported in this paper. Preliminary experiments indicate that this is the case with *H. sativum* and *U. tritici*.

1. Introduction.

During the years 1930-33, an unusually large amount of seedling blight consistently occurred among wheat plants that were being grown in an unheated section of the glasshouse for testing varietal resistance and susceptibility to flag smut. The soil was unsterilized, and of a dark, sandy, alluvial type, and the inoculum consisted of flag smut spores with which the grain was coated. At and above the soil-line, typical symptoms of seedling blight appeared. The coleoptiles changed from the normal green to brown, the leaves yellowed and withered, and the plants died after the bases of the stems were rotted through. Sometimes, the aerial mycelium of a species of *Fusarium* could be readily observed around the bases of the affected plants. The symptoms appeared on seedlings up to the time when they were about 4 inches high. Those passing that stage continued apparently normal growth until later on when symptoms of flag smut usually appeared.

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Isolations from the blighted seedlings usually yielded species of *Fusarium*, generally *F. culmorum* (W.G. Sm.) Sacc., or *Helminthosporium sativum* P.K.B. or both.

During the same period, the writer was engaged in the study of the factors influencing the degree and amount of seedling blight and other manifestations of foot rot caused by *F. culmorum*. In experiments specifically designed for this purpose, such consistently good infection as that in the flag smut trials above noted was not obtained, even though the plants were grown in sterilized soil, from seed inoculated with a heavy suspension of conidia, and under environmental conditions considered optimal for the disease.

On comparing the results in the two glasshouses, it was quite evident that a most important factor was influencing the amount of seedling blight in the flag smut experiments. That factor is shown by the experiments detailed in this paper to be the combined action of a smut and a root-rotting organism, in this case, *U. tritici* and *F. culmorum*.

2. The Organisms.

Fusarium culmorum (W. G. Sm.) Sacc.

In a previous paper(9), the writer showed that *F. culmorum* is one of the causal organisms of foot rot of wheat in Australia. Material from 87 fields out of 190 inspected during the 1932 survey of part of the Riverina, Mallee, and Wimmera districts, yielded cultures of species of *Fusarium* of the "discolor" type. A number of the isolations, representative of the districts visited in the course of the survey, were tested under glasshouse conditions, and about 90 per cent. of them were found to be pathogenic on wheat. Judged by the macroscopic appearance and pathogenicity of the isolations, they were cultures of *F. culmorum*.

The inocula used in the experiments reported in this paper were conidial suspensions from sub-cultures of the isolation from the wheat variety "Purple Straw" originally obtained from Longerenong, Victoria. This culture was selected on account of its abundant production of sporodochial conidia and its relative virulence.

Urocystis tritici Koern.

Flag smut of wheat caused by *U. tritici* Koern occurs in Australia, Japan; India, the United States of America, S. Europe, S. Africa, and China.

According to Hori(12), McAlpine(14), and Brittlebank(3), *U. tritici* is seed-borne. Verwoerd(21) reports that the spores easily adhere to the grain and are found in great numbers in the crease and brush. It is also obvious from the results of experiments that they are present in the soil in areas where flag smut occurs, and may persist in it for five years or more.

Noble(17), Verwoerd(21), and others have attempted to culture *U. tritici* on various artificial media, but without success. In the present state of our knowledge, it must therefore be regarded as an obligate parasite.

Infection by *U. tritici* is possible only during a limited period, stated by Noble(17) to be during the time when the coleoptile is less than 4 mm. in length at inoculation, and by Verwoerd (21) as being from the emergence of the coleoptile to its rupture by the first leaf.

The inoculum* used in the experiments recorded here was obtained from plants growing under field conditions, and it was therefore naturally expected that spores of other organisms were likely to be present. Under the microscope, it was observed that the samples of inoculum contained spores of *Alternaria* and a few rust spores, the former occurring very much more frequently. From time to time, platings were made, totalling altogether about twenty. Cultures of only *Alternaria* spp., *Penicillium* spp., and bacteria resulted.

3. Materials and Methods.

(i) *Grain*.—The varieties selected for pot experiments were Federation and Bomen, the former classed as relatively susceptible to, and the latter relatively resistant to, flag smut. Before inoculating and planting, the grain was washed in running tap-water for fifteen minutes. The controls were sown without further treatment, whereas other lots were inoculated by dipping them in heavy suspensions of spores of *U. tritici*, or of sporodochial conidia of *F. culmorum*, or a mixture of both, as required. The grain was sown immediately following treatment.

(ii) *Soil*.—A dark, sandy, alluvial soil obtained from a nearby river valley was used in all pot experiments, either with or without previous sterilization by steam. For those experiments in which sterilized soil was used, 6-in. pots were filled, and then steamed for four hours or more at atmospheric pressure.

4. Results of Experiments in the Glasshouse.

In all but one of the experiments, 100 grains of the selected wheat variety were sown in pots at the rate of 10 grains per pot for the control and for each of the inoculated sets. On completion of germination, and subsequently at intervals of two weeks, the seedlings were counted, and the numbers of dead plants visible were also recorded. The latter are not given in the accompanying table. As previous experience showed that whiteheads were rarely produced in pot experiments in the glasshouse, probably no useful purpose would have been served by allowing the plants to mature. Since any attempts to assess the amount of damage done by root or foot lesions involved a certain amount of error and difficulty, it was decided that, in this series of experiments, death due to the disease would be the most suitable standard to employ. In two experiments, the plants that survived the seedling stage were allowed to grow almost to maturity, and then examined. However, the majority of those in the mixed inoculum set had no lesions on the roots nor on the bases of the stems. About one-tenth were smutted, and the others were more or less affected with foot or root rot.

* The flag smut inoculum was very kindly supplied by Miss P. H. Jarrett of this Laboratory, who is at present investigating certain aspects of that disease.

Table 1 gives the results of five experiments with Federation wheat in sterilized soil, one with the same variety in unsterilized soil, and another in soil used in a previous experiment and then repeated, using the soil as the sole source of inoculum for the second experiment. Tests with the relatively resistant variety Bomen are included. The table shows that the trials were made over a period of six months, during which the temperature of the glasshouse varied considerably. The prevailing temperature seems therefore to have been a modifying rather than a limiting factor in these experiments. It follows that the results of the different experiments, as presented in the tables, should be considered separately.

TABLE 1.—SHOWING THE AMOUNT OF SEEDLING BLIGHT RESULTING FROM THE USE OF DIFFERENT INOCULA UNDER GLASSHOUSE CONDITIONS.

		Maximum stand of apparently healthy plants.	Final stand of apparently healthy plants.	Observed dead.	Per cent. stand based on final stand in controls.	Period of observation and average glasshouse temperatures.
		(A)	(B)	(A)-(B)		
Federation wheat sown in sterilized soil; 5 experiments = 450 grains	Control ..	425	406	19	100	May—14.4°C–24°C
	<i>F. culmorum</i> ..	422	388	34	95	June—12.2°C–22.2°C
	<i>U. tritici</i> ..	431	389	42	95	July—11.3°C–19.9°C
	Mixed inoculum	408	299	109	73	
Federation wheat sown in unsterilized soil; 1 experiment = 100 grains	Control ..	97	90	7	100	21st Mar.–23rd June.
	<i>F. culmorum</i> ..	97	90	7	100	
	<i>U. tritici</i> ..	99	93	6	103	
	Mixed inoculum	96	83	13	92	
Bomen wheat sown in sterilized soil; 3 experiments = 240 grains	Control ..	203	203	0	100	27th July–28th Aug.
	<i>F. culmorum</i> ..	194	157	37	77	
	<i>U. tritici</i> ..	215	187	28	90	
	Mixed inoculum	195	131	64	64	
Federation wheat in soil originally sterilized for use in a former experiment with <i>F. culmorum</i> and <i>U. tritici</i> and used again without re-inoculation of grain	Control ..	199	199	0	100	4th July–14th Aug.
	<i>F. culmorum</i> ..	167	144	23	72	
	<i>U. tritici</i> ..	187	172	15	86	
	Mixed inoculum	156	91	65	45	

The mixed inoculum produced a much higher percentage of seedling blight than either organism acting independently, the distinction being more marked in sterilized than unsterilized soil. Certain factors other than temperature, as above noted, which interfered with quantitative replication of results, are being investigated. Experiments with a mixed inoculum consisting of *H. sativum* and *U. tritici* in sterilized soil under glasshouse conditions have so far given results paralleling those above, but sufficient data to warrant presentation of figures are not yet available. No seedling blight was observed, but a number of seedlings showed lesions, which in many cases extended along the sheaths of the

lower leaves. Other lesions were observed on the laminae. In contrast with this, at no examination so far made of the plants in this experiment, and only very occasionally in the course of other experiments during the past three years, were lesions noticed on stem bases or leaves of plants arising from grain inoculated with *H. sativum* only.

Isolations from the stem and leaf lesions of the infected plants yielded cultures of *H. sativum*.

5. Pot Experiments Out-of-Doors.

It is well known that out-of-doors a more nearly normal type of growth is obtained, even in pot experiments. That was not, however, the original purpose in trying the first of this series outside, which was to observe the effect of the disease at a lower temperature than could be obtained in the glasshouse. The results are shown in Table 2. The disease was not expected in the

TABLE 2.—SHOWING THE AMOUNTS OF SEEDLING BLIGHT RESULTING FROM THE USE OF DIFFERENT INOCULA IN POTS OUT-OF-DOORS.

		Maximum stand of apparently healthy plants.	Final stand of apparently healthy plants.	Observed dead.	Per cent. stand based on final stand in controls.	Period of observation and temperatures.
		(A)	(B)	(A)-(B)		
Federation wheat in sterilized soil; 1 experiment = 100 grains	Control ..	96	96	0	100	5th May—21st July 5th May—18th = 14 days after planting, av. temp. 3°C–17°C av. temp. June.— 4·7°C–13·3°C; av. temp. July.—8·6°C –15·5°C
	<i>F. culmorum</i> ..	96	89	7	92	
	<i>U. tritici</i> ..	100	94	6	98	
	Mixed inoculum	94	44	50	46	
Federation wheat in unsterilized soil	Control ..	98	98	0	100	14th June–28th Aug.
	<i>F. culmorum</i> ..	95	93	2	94	
	<i>U. tritici</i> ..	93	91	2	92	
	Mixed inoculum	98	89	9	90	
Bomen wheat in steril- ized soil	Control ..	100	100	0	100	14th June–7th Aug.
	<i>F. culmorum</i> ..	96	92	4	92	
	<i>U. tritici</i> ..	97	96	1	96	
	Mixed inoculum	94	61	33	61	
Bomen wheat in un- sterilized soil	Control ..	97	97	0	100	30th May–15th Aug.
	<i>F. culmorum</i> ..	97	95	2	98	
	<i>U. tritici</i> ..	95	95	0	98	
	Mixed inoculum	96	89	7	92	
Federation wheat in sterilized soil. After a fortnight in the glasshouse the pots were removed to a bench out-of-doors	Control ..	185	178	7	100	26th June–3rd Aug. Average temper- ature in glasshouse after planting 12°C –20°C
	<i>F. culmorum</i> ..	193	175	18	98	
	<i>U. tritici</i> ..	185	180	5	101	
	Mixed inoculum	173	113	60	63	

virulent form obtained in the comparatively warm conditions prevailing inside, because the optimal temperature for infection by *F. culmorum* is from 18°C.-22°C. On several occasions in May, the temperature outside rose to about 20°C., but was not maintained for more than an hour or two, even during the hottest part of the day. On the other hand, in the same month, it was often only just above freezing-point at 9 a.m. According to records of soil temperature made during May, the average minimum and maximum, taken at 9 a.m., and noon at a depth of 1 inch, was 3°C. and 17°C. respectively. Lower average temperatures prevailed during the succeeding winter months, when a number of frosts occurred at night. The average soil temperatures, also taken at 1 inch at 9 a.m. and midday respectively in June, were 4.7°C. and 13°C., and in July, 8.6°C. and 15.5°C. Watering was not required as often as in the glasshouse, since occasional showers and heavy dews contributed to the supply of soil moisture.

It will be observed from Table 2 that the trend of the results is essentially the same as in Table 1, in that the percentage stand in pots which were sown with grain treated with the mixture of the two organisms was much lower than in the other sets (Plate 3).^{*} Seedling blight was produced more slowly by the mixed inoculum in unsterilized soil than in sterilized soil.

From the diseased plants in the mixed inoculum sets, cultures of *F. culmorum* were repeatedly obtained.

6. Field Experiments.

Four plots, each measuring 48 feet x 12 feet, separated by 4 feet pathways, were prepared for preliminary field trials in May, 1933. The soil of the experiment area was a light-coloured, silty loam, somewhat deficient in humus, and was used for experimental work with *F. culmorum* during the previous season. Plot No. 1, used as a control, was sown with uninoculated grain, No. 2 with grain inoculated with spores of *U. tritici*, No. 3 with *F. culmorum*, and No. 4 with a mixture of both these organisms. Twelve varieties of wheat were chosen for trial, viz., Canberra, Federation, Aussie, Caliph, Gluyas, and Waratah, reputedly susceptible to flag smut, and Bomen, Bunyip, Cedar, Galgalos, Geeralying, and Nabawa, classed as resistant. Rows of resistant and susceptible varieties alternating were planted 1 foot apart, each with 39 grains at intervals of 4 inches.

The original purpose of the tests was to compare the effects of the three inocula on the plants at maturity, but during an examination made in June, when the plants had begun to tiller, it was evident that the organisms in the mixed inoculum plot were already causing an appreciable and unexpected amount of seedling blight.

No records of soil temperature were taken at the depth at which the grain was sown, i.e., approximately 1½ inches, but it may be judged from the average minimum and maximum air temperatures and the soil temperatures at 4 inches below the surface. During the first fortnight following planting, the average minimum and maximum temperatures of the air were 5.5°C. and 14.7°C. In May, the average minimum and maximum temperatures of the soil at 4 inches were 8.9°C. and 11.7°C., in June 5.6°C. and 8.3°C., and in July 5.6°C. and 7.8°C.

^{*} For Plates see facing page 308.

In the accompanying table, the stand of each variety in the control plot on 22nd June and 1st August, is compared with those in the three inoculated plots. The percentage stands, on 1st August, of plants of each variety in the mixed inoculum plot are calculated on the basis of the number in the controls. The total numbers of plants standing on the stated dates, and the percentage stand in each plot on 1st August, are also given. A striking feature in this table is the large number of

TABLE 3.—SHOWING THE AMOUNT OF SEEDLING BLIGHT IN SUSCEPTIBLE AND RESISTANT VARIETIES UNDER FIELD CONDITIONS.

Varieties.	Date of Examination.	Control Plot.		Flag Smut Plot.		Mixed Inoculum Plot.		<i>F. culmorum</i> Plot.		Percentage Stand in Mixed Inoculum Plot.
		Apparently Healthy Plants.	Dead.*	Apparently Healthy Plants.	Dead.*	Apparently Healthy Plants.	Dead.*	Apparently Healthy Plants.	Dead.*	
Bomen (R) ..	(a)	138	..	123	..	100	4	130	3	63
	(b)	132	..	118	..	84	1	128	..	
Canberra (S) ..	(a)	140	..	130	..	110	9	131	..	54
	(b)	137	..	120	..	74	3	130	..	
Bunyip (R) ..	(a)	132	..	130	..	94	1	126	..	63
	(b)	131	..	120	..	83	2	121	..	
Federation (S) ..	(a)	147	..	141	..	89	8	134	1	45
	(b)	138	..	119	..	63	..	127	..	
Cedar (R) ..	(a)	134	1	137	1	112	1	129	..	79
	(b)	124	..	137	..	98	1	126	..	
Aussie (S) ..	(a)	107†	1	132	..	108	6	133	..	56
	(b)	100	..	113	1	75	1	128	..	
Galgalos (R) ..	(a)	135	1	134	..	117	5	137	..	75
	(b)	129	..	122	..	97	..	137	..	
Caliph (S) ..	(a)	131	1	138	..	95	3	128	..	54
	(b)	131	..	118	3	71	4	119	..	
Geeralying (R) ..	(a)	133	..	139	..	100	1	122	1	69
	(b)	124	..	129	..	86	2	113	..	
Gluyas (S) ..	(a)	124	..	139	..	107	20	128	1	58
	(b)	121	..	120	2	71	6	115	..	
Nabawa (R) ..	(a)	141	2	135	2	105	3	133	1	70
	(b)	124	..	124	..	88	3	125	..	
Waratah (S) ..	(a)	136	..	138	1	74	4	132	1	43
	(b)	132	..	128	..	57	1	127	..	
Totals on 22nd June ..		1,598		1,616		1,211		1,563		
Totals on 1st August ..		1,523		1,468		947		1,496		
		= 100%		= 96.4%		= 62.2%		= 98.2%		
		stand		stand		stand		stand		

(a) = 22nd June.

(b) = 1st August.

* These plants were dead at the time of counting, but had not yet rotted away.

† Only three rows of this variety were sown as controls. In all the others there were four rows.

dead plants seen and counted in the mixed inoculum plot as compared with the scattered few in the others on the day the plants were counted.

As the first count was made on 22nd June, 43 days after planting, it is logical to assume that the low stand in the mixed inoculum plot was due to pre-emergence blight and seedling blight caused by the two organisms.

The plots were not arranged with a view to statistical analysis of the results, but comparison of the stands of each variety in the mixed inoculum with the control plot on 1st August shows striking differences. The varieties classed as susceptible or resistant to flag smut appear to be also relatively susceptible or resistant to the mixed inoculum. It was observed at each examination that the plants in the control and in the *F. culmorum* plots were about the same height, whereas those in the flag smut and mixed inoculum plots were definitely stunted.

7. Discussion.

That *F. culmorum* is an independent parasite on wheat, causing seedling blight and other symptoms of foot and foot rots, has been shown by Appel (1), Bennett (2), and the writer (9). Simmonds (20) has also found that it is parasitic on oats, on which it causes similar symptoms. Although the pathogenicity of this and other foot rot organisms has been proved, no adequate explanation based on experimental evidence in the glasshouse or in the field has hitherto been offered to account for variation in the extent and intensity of their attacks in the same or in different fields from year to year.

Experiments recorded in this paper show that when grain is inoculated with spores of both *F. culmorum* and *U. tritici*, the percentage of seedling blight under glasshouse or field conditions is much higher than that produced by *F. culmorum* alone.

McKinney (15), McKinney and Davis (16), and Dickson (5), found that soil temperature and moisture greatly influenced the amount and severity of foot rot caused by *H. sativum*, *Ophiobolus graminis* (Berk.) Sacc., and *Gibberella saubinetii* (Mont.) Sacc., respectively. Although in controlled temperature experiments, foot and root rotting has been produced by *F. culmorum* over the whole range tried, i.e., 10°C.-30°C., the optimum temperature for seedling blight appears to lie between 18°C. and 22°C. when the soil moisture is adjusted to 60% of its capacity. In pot experiments in sterilized and unsterilized soil out of doors, seedling blight occurred among plants in the mixed inoculum sets when the average temperature varied from 4.7°C. to 13.3°C. Furthermore, in the mixed inoculum plot in the field, seedling blight was observed when the average soil temperature range was 8.9°C.-11.7°C. in May, 5.6°C.-8.3°C. in June, and 5.6°C.-7.8°C. in July, whereas there was practically none in the adjoining plot in which the grain was sown after being inoculated with *F. culmorum* only. It is clear from these figures that when grain is inoculated with the two organisms, seedling blight occurs abundantly in the field or in pots out-of-doors at lower temperature than would ordinarily be expected from the results of controlled temperature experiments with *F. culmorum*. According to Faris (7), the amount of flag smut depends on both soil temperature

and moisture. He found that between 10°C. and 20°C., and with fairly dry soil, a high percentage of infection was obtained. When the soil moisture was 40%, high infection occurred only when the grain was germinated between 10°C. and 15°C. If the soil moisture approached saturation, extensive infection occurred at 10°C., but dropped rapidly above and below that point. In our work, when grain is inoculated with both *F. culmorum* and *U. tritici*, a greater amount of seedling blight results over a wider range of temperature, irrespective of whether sterilized or unsterilized soil is used in the experiment.

Fellows (8), Henry (11), and Broadfoot (4) report on the marked difficulty in producing cereal foot rots in field experiments, even when the soil is heavily inoculated, and other conditions so far as they are known, are satisfied. Henry (10), and Sanford and Broadfoot (19), suggest that the loss in virulence of *H. sativum* and *O. graminis*, respectively, in field experiments, is due to the controlling or suppressive action of the soil microflora. Attempts by the writer and others in this laboratory to produce well-marked foot rot symptoms by artificial inoculation of the soil in experimental field plots have not been altogether successful, and in certain cases have almost entirely failed to produce a large amount of rotting. On the other hand, it is commonly known that sometimes the disease occurs in severe form under field conditions. The results reported here provide a partial explanation of such attacks, the variation in the amount and severity being perhaps correlated with soil temperature and moisture during germination. The occurrence of thin stands or even stunted plants such as are frequently found in areas affected with foot rot may be in great measure due to joint attack by one of the smuts and one or more of the foot rot organisms. Experiments are now in progress with other smuts, in combination with *F. culmorum* and other foot rot organisms of wheat, barley, and oats.

That the manifestation of a disease caused by one organism may be intensified as a result of the action of another has been noted by other investigators. Dillon Weston (6) in experiments on the control of bunt, observed that smutted wheat plants were more heavily attacked by *Puccinia glumarum* Eriks. & Henn., than were healthy plants. Welsh (22), found a similar relationship existing among oats, in that smut-infested plants were more heavily rusted than the non-smutted.

The present investigation provides another example of the intensifying effect of one of the smuts on other diseases. It is, however, different from the cases just cited, because under field conditions, seedling blight occurs before the symptoms of flag smut would ordinarily appear or even be suspected. Jarrett (13) states that certain wheat varieties "may show infection in one or two tillers only, or be quite healthy, while microscopic examination will reveal the fungal hyphae in the base of the plant. Record of this type of infection is lost in the usual infection counts, and the actual effect of the disease can only be estimated by an analysis of yield." According to Noble (17) and Verwoerd (21), flag smut does not appear earlier than the fourth or fifth leaf stage. Jarrett, (13) states that flag smut symptoms usually appear very much later in plants grown in the field than under artificial conditions.

In the mixed inoculum plot in the field, not only did a higher percentage of seedling blight occur than in plots with either organism alone, but a difference was observed between the amount of blighting of the varieties susceptible or resistant to flag smut, being greater among the former than the latter. The percentages in Table 3 show this clearly.

That the two organisms may occur together on the grain or in the soil, or that smutted grain may be planted in soil containing the foot rot organisms, obviously happens in our wheat-growing areas, and according to this work, the combined attack results in seedling-blight.

It appears probable that flag smut or other smuts in combination with one or another of the foot rot organisms may, under certain environmental conditions, produce definite basal lesions on the culms of older plants, and other symptoms of foot and root rots. Sampson and Walters Davies (18) found that bunted plants were more than ordinarily susceptible to attacks by *Fusarium* spp., and were of the opinion that this was the probable reason for the cause of mortality among bunted plants. The results reported here on the combined effect of *U. tritici* and *F. culmorum* are similar to those just cited.

Further study of the reaction of cereals to infection by the smuts and root-rotting organisms is in progress.

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Carbon Tetrachloride.

A Note on its Toxicity for Sheep.

By D. T. Oxe^r, B.V.Sc.*

The observations described in the brief note that follows were made by Mr. Oxe^r when he was an officer of the Tasmanian Department of Agriculture and when he was working on a programme of research being carried out by the Council under the Australian Pastoral Research Trust-Empire Marketing Board scheme (see this *Journal*, 4: 133, 1931).—Ed.

1. Introduction.

The toxicity of carbon tetrachloride for sheep has from time to time been given some prominence in Australia. Ross and McKay (1), in advocating its use for the elimination of the liver fluke, have reviewed some phases of the question, while, more recently, Rose (2) has surveyed mortality following treatment of flocks in New South Wales.

Although they have been previously recorded (3), we here wish to emphasize toxic symptoms which occurred in an experimental flock of sheep following routine treatment with the drug. These sheep were being used in certain experimental feeding trials carried out in Tasmania in relation to pregnancy paralysis of ewes.

2. Toxic Symptoms in the Experimental Flock.

The flock consisted of 118 full-mouth and six-tooth Romney-Southdown ewes, which had been mated to Southdown rams. The ewes were in very good condition, and had been selected as being of a type susceptible to the disease under investigation. They were divided into four groups, each being maintained on such a small area (less than one acre) that hand-feeding was their sole means of sustenance. The rations consisted of a mixture of best oaten and lucerne chaff, with the addition of a small amount of oats and bran in the case of three of the groups. Salt was available as a lick, while one-half ounce of bone flour per sheep per day was mixed in the rations for a period of three months prior to the fourth drenching.

It was thought that such a concentration of sheep on a small area would ultimately lead to a heavy parasitic infestation, particularly as the same ground had been heavily stocked with sheep a short time previously. To keep the parasitic infestation as low as possible, it was considered advisable to commence routine treatment with carbon tetrachloride. This was accordingly carried out, the dose used being 2 c.c. of the drug in 3 c.c. liquid paraffin. The best quality procurable was obtained and was mixed in the laboratory prior to treatment.

The use of the drug was followed by toxic symptoms, which would have been classified as mild had not the exact amount of feed consumed per day been known, for, apart from loss of appetite, the only symptoms

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shown were somnolence and lethargy. No noticeable gastro-intestinal disturbances were present. The appearance of toxic symptoms was rather unexpected, but those shown after the first two treatments did not appear sufficiently severe to warrant discontinuance of treatment. The effect of the third, however, was serious, and as a fourth showed that toxic symptoms were equally severe as those previously seen, drenching was discontinued.

In Table I., figures are given showing that the appetite was greatly depressed, that this depression appeared at varying periods after treatment, and that the period of inappetence tended to increase with each successive administration of the drug.

TABLE I.

—	First Drenching.	Second Drenching.	Third Drenching.	Fourth Drenching.
Average daily amount (over one week) eaten by all groups before drenching	240 lb.	400 lb.,	400 lb.	441 lb.
Average daily amount eaten during period of inappetence	150 lb.	276 lb.	266 lb.	241 lb.
Appearance of symptoms after drench- ing	2nd day	Same day	Same day	1st day
Return to normal	4th day	6th day	11th day	9th day

Appetite was slightly depressed at the beginning of each "toxic period," and then gradually returned to normal. The greatest reduction in the amount of food eaten occurred on the first day after the fourth treatment, when only 30 lb. of food were eaten by all groups. The loss of, and return to, appetite following the third and fourth drenchings are illustrated graphically in Fig. 1.

Drowsiness was well marked at the onset, but had the sheep been under field conditions, it would have taken close observation to detect anything unusually wrong, apart from the symptoms in the initial stages of each period.

3. The Effect of Carbon Tetrachloride on the Liver.

In dogs, toxic symptoms following the usual latent period of some hours, are constantly accompanied by central necrosis of the liver lobules. Gardner et alii (4) state that this necrosis, which may be caused by doses as low as 0.176 c.c. per kilo of body weight, may be observed as early as 8 hours, and that the maximum damage occurs in 48 hours after treatment. According to Davis (5), even extremely

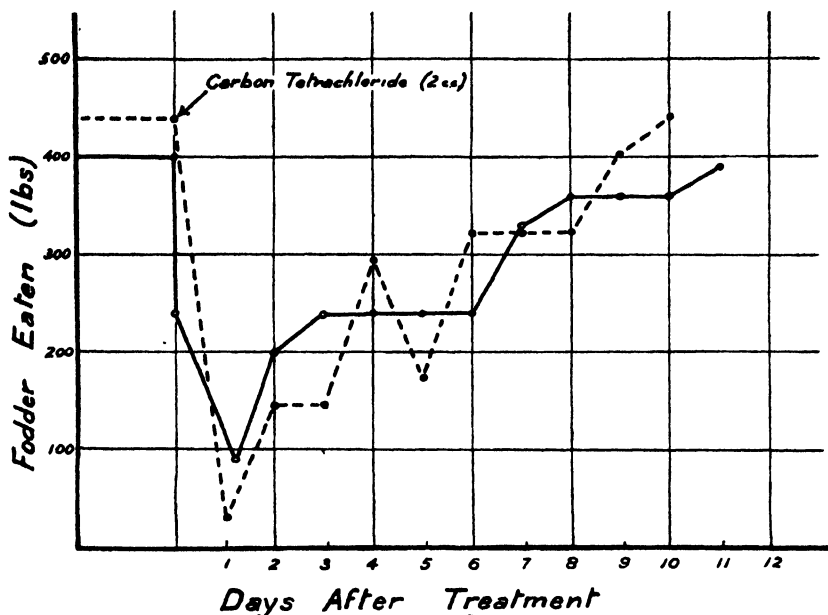


FIG. 1.—Graphs illustrating loss of appetite in sheep after drenching with 2 c.c. of carbon tetrachloride. The full line illustrates the effect of the 3rd drenching, and the dotted line the effect of the 4th drenching of the same animals some 4 weeks later.

small doses will be followed by liver injury as judged by fatty degeneration. Lamson and Wing (6) consider that a threshold dose of from 0.5 c.c. to 1 c.c. per kilo is necessary before liver necrosis can occur. Minot (7, 8) and Cutler (9, 10) consider that an excess of guanidine in the blood, following liver necrosis, is responsible for the symptoms shown, this being supported by the fact that the injection of guanidine hydrochloride gives rise to symptoms identical with those caused by carbon tetrachloride, and that both are relieved by calcium therapy. Factors other than liver necrosis are necessary, however, for the production of clinical symptoms, as it has been shown (6) that, notwithstanding a tremendous amount of liver necrosis following large and frequently repeated doses, dogs may not only remain normal to all appearances, but even gain in weight.

With the exception of Rose's statement that livers of sheep which died from the effects of carbon tetrachloride showed no evidence of liver necrosis on microscopic examination, there are no references, in the literature available, to the pathology of the liver in sheep and cattle which have succumbed to this drug. Seddon (11) has informed us that in no case has he found liver necrosis in sheep which have died following administration of therapeutic doses up to 2.5 c.c. Ross (12) also has found no evidence of necrosis following therapeutic doses, although in some sheep treated at regular intervals he has found indications of fatty degeneration.

With a view to determining whether a large, as compared with a therapeutic dose, is capable of causing liver lesions, the following experiment was carried out.

Two sheep were used. Both were in a fat and well-nourished condition. For the previous four months they had been fed on oaten chaff, in addition to which they had had access to small paddocks in which grass picking was available.

Sheep No. 1, weighing 115 lb., was drenched on 31st July, 1933, with 2 c.c. carbon tetrachloride in 3 c.c. liquid paraffin. On the first day after treatment, there was noticeable loss of appetite with a tendency to remain aloof from the others. The sheep was slaughtered 52 hours after treatment. No abnormality was revealed on post-mortem examination. Microscopically, the liver appeared normal, but hyaline degeneration of some of the convoluted tubules of the kidney was present.

Sheep No. 2, weighing 105 lb., was drenched on the same date with 15 c.c. carbon tetrachloride in the same proportion of oil. Similar, though more marked, symptoms occurred as in the case of *Sheep No. 1*. Post-mortem examination revealed a marked lobular necrosis of the liver, involving, on a rough estimate, about 50 per cent. of liver tissue. The internal fat showed a slight, but distinctly yellowish, discolouration. No other abnormalities were observed. On microscopical examination of the liver, necrosis of cells in the central portion of the lobules, accompanied by intense congestion, was seen. The kidney was normal.

Although a small experiment, this indicates that a therapeutic dose of carbon tetrachloride causes no liver necrosis, although a large dose may do so to a very marked degree. It also indicates that there may be a different mechanism of intoxication in sheep to that occurring in dogs, and is confirmatory evidence that liver necrosis is not essential for the production of toxic symptoms.

4. Discussion.

Considerable experience has now been gathered regarding the toxicity of carbon tetrachloride for those animals in which its therapeutic use has been most practised, and on reviewing the literature on the subject, one is at once struck by the similarity in different species of (a) the wide extremes in tolerance, (b) symptoms, and (c) post-mortem lesions—with the exception of sheep which, although agreeing in other respects, do not show liver necrosis following the usual medicinal doses.

With dogs, in which the greatest amount of experimental work has been carried out, it has been shown that certain conditions predispose to toxic symptoms, while other conditions seem to have the reverse effect. Briefly summarizing these, it has been shown that starvation, the addition of alcohol to the food, and diets rich in protein or fat or deficient in calcium, are factors for toxicity, while normal mixed diets or those rich in calcium or carbohydrate are factors for safety. Acidity or alkalinity of the food may possibly be factors for toxicity or safety. Magnesium sulphate may increase the safety of the drug.

Owing to the similarity of reaction to the drug in various animals, one would expect that the results of experimental work in dogs would also apply, in principle, to animals of other species. This view is supported by the experiments of Hindmarsh (13), in which he has

shown that cattle, after being rendered deficient in calcium and phosphorus, may be made susceptible to, or tolerant of, the drug by withdrawing or feeding bone meal. Field evidence indicates that the same condition holds for sheep, although we are aware of very "deficient" flocks which show no adverse effects following even regular routine treatment. Other factors suspected of rendering sheep more susceptible are the feeding of concentrates, depasturing on certain crops, or an excessively fat condition. In addition, Rose has suggested that cold, bleak weather may be a predisposing cause. The fact that sheep do not show liver necrosis may be explained by the difference in metabolism in the herbivorous, as compared with the carnivorous, animal.

In the experimental flock described, it is noteworthy that the after effects of the third and fourth drenchings were more severe than those of the first and second. This may have been due, partly, to the effect of repeated treatments, but more probably to an increasing time on a ration which rendered the animals susceptible. The component part of the ration responsible for this susceptibility may have been either the oat grain or the lucerne chaff or both. Calcium deficiency may definitely be eliminated, as, apart from the ration being of itself fairly plentifully supplied with this element, bone flour, which was mixed through the ration, failed to decrease the toxic symptoms shown. From experience with this and other flocks, adverse weather conditions are not considered to have been of importance in rendering this flock susceptible.

Although the actual cause of symptoms in these sheep is uncertain, it is considered important that such a marked effect on appetite can be caused, and yet only mild symptoms of toxæmia result. Rose has shown that in the field a dose of 1 c.c. of carbon tetrachloride may be followed by severe mortality, and in some cases by loss of wool in the survivors. It is more than probable, therefore, that in quite a large percentage of flocks regularly treated with 2 c.c. a marked loss of appetite may be shown, extending over possibly quite long periods, although only accompanied by mild symptoms and unobserved under field conditions.

It is conceivable that the loss of weight and the likelihood of faults in the wool following such severe checks would counterbalance the beneficial effect of the drug, especially when, as is often the case, it is being used for the control of a not very heavy worm infestation. Ross and Graham (14, 15) have shown that, under the conditions of their experimental trials, no such ill effects, as judged by loss of body weight and examination of the wool did occur, and Marston (16), in the experimental flocks under his control, and in which regular weighings are practised, has no reason to suspect that the routine drenching with the drug has caused any ill effects, but it must be remembered that these experimental flocks represent a very small proportion of the total flocks treated throughout Australia, and do not, therefore, necessarily prove that such adverse effects do not occur. On the contrary, the experience recorded above proves that they may occur.

In carbon tetrachloride, the veterinarian has in his hands a very efficient agent, but it must be borne in mind that it is a therapeutic and not a preventive agent. There are, however, contra-indications

for its use, of which one is definitely calcium deficiency. Regarding the others, there is at present some confusion and, although it can be said that, as in the dog, they rest mainly on the effect of diet or constituents of diet on metabolism, they require to be more accurately defined before the drug can be regarded as safe for wide and general use.

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Fruit Bud Studies.—II. The Sultana: Differentiation and Development of the Fruit Buds.

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Summary.

1. The results of a study of the differentiation and development of the fruit buds of the sultana vine at Merbein, Victoria, during five consecutive seasons, are reported in this article.

2. It is shown that:—

- (i) Tendril and inflorescence primordia differentiate from morphologically similar anlagen.
- (ii) The development of anlagen as inflorescence primordia or as tendril primordia is correlated with the time of the season during which the growth of the anlagen occurs.
- (iii) Differentiation of anlagen into inflorescence primordia takes place during late spring, summer, and autumn; whilst anlagen which are initiated after the winter rest become tendril primordia. Differentiation of an anlage into a primordium is defined as the acquisition of the mode of growth characteristic of the organ developed therefrom.
- (iv) Anlagen which are initiated in late summer or autumn and have not developed sufficiently before winter to acquire a definite habit of growth become tendril primordia during the following spring, whilst anlagen which had just begun to acquire the inflorescence mode of growth in autumn, develop into "transition" forms when growth recommences.
- (v) Differentiation of the flowers of the inflorescence occurs as the buds are opening in spring and prohibits further ramification of the inflorescence.

3. It is concluded that:—

- (i) The number of anlagen which differentiate as inflorescence primordia is determined by the rate of their development during summer and autumn. The rate of development of the anlagen during this period is therefore an important factor in determining the yield of the following season.
- (ii) The potential size of the inflorescences is determined by the amount of growth made by the primordia prior to bud burst in spring.
- (iii) Conditions which induce an early cessation of elongation growth in the shoots, and are favorable to the rapid accumulation of starch in the wood, appear to be conducive to the differentiation of anlagen as inflorescence primordia and their rapid development as such.

1. Introduction.

In the first paper of this series⁽¹⁾ it was concluded, *inter alia*, that—

- (a) yield in the sultana is correlated with the number of fruit buds formed in the previous year.
- (b) the number of fruit buds formed is low towards the base of the cane, increases progressively outwards, and falls off towards the distal end in all except very short canes.

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(¹) This Journal, 5: 47-52, 1932.

- (c) the seasonal variation in the proportion of fruit buds produced is considerable, and is largely dependent upon the number of fruit buds formed on the distal half of the cane, and
- (d) the appearance or initiation of the primordia (then designated "differentiation of the primordia") could be determined by microscopic examination, and, in the season of 1928-29, occurred in the basal buds about the 12th of November.

The present paper records the times of initiation of the primordia for a further four seasons, and describes their development from the time of differentiation to flower production in the following spring.

The additional data secured during these studies, however, render it necessary to modify the terminology used in the first article of the series⁽¹⁾. The primordia, at the time of their initiation, are not necessarily potential inflorescences, and in fact they may develop into any one of the following three structures:—(i) inflorescences, (ii) transition forms between inflorescence and tendril, and (iii) tendrils.

The actual differentiation of the primordia as inflorescence primordia occurs relatively slowly and progressively as the primordia acquire the mode of growth characteristic of the inflorescence. The term *anlagen* is therefore applied hereafter by us to primordia which have not yet differentiated into one of the above three structures⁽²⁾.

The facts which have led to this conception and the importance of making this distinction are explained in Section 2 (A). Suffice to say that this interpretation helps to explain the distribution (*vide* (b) above) of fruitful buds on the cane, and also throws considerable light on the causes of the variation in the proportion of fruit buds formed from year to year. At the same time, the importance of the period during which the first *anlagen* are formed is diminished by the fact that the differentiation of the *anlagen* into inflorescence primordia takes place progressively and may continue throughout the season. The fact remains, however, that the *anlagen* produced early in the season do, almost without exception, differentiate into inflorescence primordia. It has to be determined, therefore, whether the time of the initiation of the first *anlagen* has any influence upon their differentiation into inflorescence primordia and subsequent development.

(1) *This Journal*, 5: 47-52, 1932.

(2) The term *primordium* is usually applied to a developing organ or part of an organ during its early stages of growth. The term, qualified by a substantive such as leaf, flower, or sepal, is used synonymously with the term *rudiment*, *initial*, or *anlage*. A *primordium*, so qualified, designates the organ from the time of its origin as a localized meristematic growth until the time when all the parts of the organ have been differentiated. A rudimentary flower, which has differentiated calyx, corolla, and androecium initials, but in which the gynaecium initial has not arisen, is still termed a flower *primordium*.

In the case of a rudiment which may develop into one of several types of structures, there is no single term which can be applied to the rudiment prior to the development of the mode of growth characteristic of one of the structures. A rudiment, for example, which may develop as a foliage leaf, a scale, or a bract, is spoken of as a cataphyllary *primordium*. As soon as characteristics of leaf scale or bract develop, it becomes a leaf, scale, or bract *primordium*.

It would appear desirable, however, to modify the terminology so that the same term is not applied to both the undifferentiated and the differentiated *primordium*. In view of the fact that the terms "*primordium*" and "*rudiment*" are the most commonly used ("*initial*" being generally regarded as indicating histological origin), it has been deemed preferable to select the term "*anlage*" to designate the undifferentiated *primordium*. The term "*primordium*" (or "*rudiment*") is, in this paper, restricted to describe developing structures which exhibit the characteristic mode of growth of the resultant mature structure or organ.

2. Investigational Work.

A. Initiation of Anlagen during Five Seasons.

The results obtained during the past five seasons are summarized in Table I. The data show that the time of initiation of the first anlage varied slightly in different seasons, taking place earliest in 1931 and 1930, and latest in 1932 and 1928. It has not been possible, however, to correlate the time of anlagen initiation with the tendency to form a high proportion of inflorescence primordia. Counts, made in the spring, of the number of fruitful shoots, together with the yields at the subsequent harvests, are also shown in the Table. Under normal conditions bud counts and subsequent yields are fairly closely correlated; this fact is evident from the figures of the experimental plot. Variations in the times of initiation in different seasons are not large enough to warrant any comparison with subsequent bud development or resultant yields. However, if any conclusion is to be drawn from the data, it is to the effect that the number of fruit buds formed in any season is not related to the time of initiation of the first anlage in the buds.

TABLE I.—PERIOD OF INITIATION OF ANLAGEN IN SULTANA BUDS DURING FIVE CONSECUTIVE SEASONS, TOGETHER WITH BUD COUNTS DURING THE SPRING AND YIELDS AT HARVEST FROM ONE EXPERIMENTAL FIELD.

Time of Initiation of First Anlage.	1928.	1929.	1930.	1931.	1932.
Buds 1-4 of shoot (Base)	First night fort- in Nov.	End of Oct. and first week in Nov.	End of Oct.	End of Oct.	First week in Nov.
Buds 5-10 of shoot (Middle)	Third and fourth weeks in Nov.	Mid-Nov. in rapid suc- cession	Mid-Nov. in rapid suc- cession	First night fort- in Nov.	Mid-Nov. and third in Nov.
Buds 11-16 of shoot (End)	Second week in Dec.	End of Nov. and first week Dec.	Mid-Nov. to third week in Nov.	Mid-Nov. to third week in Nov. in rapid suc- cession	First week in Dec.
Percentage bud count in following spring. Fruitful shoots of total buds	1929.	1930.	1931.	1932.	
	42%	23%	35%	37%	
Yields at subsequent harvest. Dried weight, tons per acre	1930.	1931.	1932.	1933.	
	1.85	0.47	1.38	1.80	

In most other fruits, the fruit buds are either produced on spurs or on comparatively short shoots, and the development of the buds on different parts of the shoot or tree takes place more or less synchronously. Under such circumstances, it is possible without much difficulty to

examine sufficient material to warrant a generalized statement applicable to the season. In the vine, on the other hand, the fruit buds are produced on long shoots, and they develop in acropetal succession. It is necessary, therefore, to determine the time of initiation in each bud from the base to the apex of the shoot, and to replicate these observations, at each examination during the season.

In view of the difficulties involved in determining the time of initiation for the season, and also in consideration of the unpromising nature of the results obtained over a period of five seasons, the attack on the problem along these lines has been discontinued.

B. Fruit Bud Development During Summer and Autumn.

The structure and organization of the buds as well as the differentiation of the anlagen into inflorescence primordia have been described in the first article of this series. The following account continues the description of the development of the buds during summer and autumn.

By the middle of November, the eighth leaf rudiment has arisen in the majority of buds. The first anlage to arise is usually situated opposite this leaf, and, if developed, differentiates later into an inflorescence primordium. Occasionally, an anlage is developed at the 7th embryonic node, but only rarely at a lower one. On the other hand, if the first anlage is developed opposite the ninth leaf, it may or may not develop as an inflorescence primordium.

By the beginning of December, the ninth leaf is arising in most buds, though the 10th, 11th, and 12th leaf rudiment may have been formed in the buds borne on the lower portions of the shoot. Towards the middle of December, the 10th leaf rudiment arises and very often a 2nd anlage may be observed at the ninth embryonic node.

Development generally ceases when twelve to thirteen leaf rudiments have been formed, though the time at which it occurs varies according to the position of the bud on the shoot. In the basal buds, the 12th or 13th leaf rudiment has generally been formed by the end of December, whilst the majority of buds have not progressed to this stage until about the middle of March.

The stage of development reached by a number of buds, collected from the 9th to 11th nodes during March, is shown in Table II.

The first 14 buds represented in the Table are strong and advanced, whilst the remainder are more typical of the normal fruit bud. At this time, the first formed anlage, usually opposite the 8th leaf rudiment, has developed into a comparatively large and well formed inflorescence primordium which has attained the proportions represented in Table II. The anlage opposite the 9th leaf, however, varies considerably in size, and only shows the characteristics of an inflorescence primordium in advanced buds. In this connexion, it will be observed from Table II. that the anlagen, by reason of their dimensions, fall into two fairly distinct classes. Firstly, those at the 8th and 9th embryonic nodes in the advanced buds and those at the 8th in the normal buds form a class with dimensions greater than 0.40×0.30 mm. The anlagen at higher embryonic nodes fall into a group having dimensions less than 0.20 mm. \times 0.18 mm. It may safely be stated that the primordia included in the 1st class will develop into inflorescences, those in the 2nd class into tendrils, and those of intermediate dimensions will in all probability become transition forms between tendrils and inflorescences.

TABLE II.—THE DIMENSIONS IN MILLIMETRES AND POSITION OF ANLAGEN DEVELOPED IN 25 BUDS ON 16.3.1932.

—	7th Node.	8th Node.	9th Node.	10th Node.	11th Node.	12th Node.	13th Node.
180 x .68	.40 x .32	..	.08 x .08	.06 x .06	..
268 x .56	.48 x .32	..	.08 x .08	.06 x .04	..
376 x .40	.40 x .32	..	.12 x .10	.06 x .06	..
4 ..	.80 x .80	.52 x .44	..	..	.16 x .16	.08 x .10	..
572 x .68	.56 x .52	..	.12 x .08	.08 x .08	..
664 x .56	..	..	.20 x .12	.06 x .06	..
780 x .76	.64 x .56	..	.12 x .06	..	Arising
860 x .68	..	.12 x .08	..	Arising
972 x .72	..	.16 x .12	..	..	Arising
1070 x .64	.40 x .36	..	.12 x .16	.10 x .10	..
1172 x .72	.60 x .48	..	..	.10 x .08	..
1264 x .72	.32 x .24	..	..	.12 x .12	..
1368 x .60	..	.16 x .16	.08 x .08	..	Arising
1480 x .60	..	.12 x .12	.10 x .08	..	Arising
Percentage frequency	7	93	65	21	70	65	36
Mean area Sq. Mms.	.64 (.80 x .80)	.44 ± .03 (.71 x .62)	.22 ± .04 (.48 x .42)	.02 (.14 x .18)	.012 ± .002 (.10 x .11)	.007 ± .001 (.08 x .08)	..
1572 x .72	.20 x .16	..	.08 x .06	Arising	..
1648 x .36	.16 x .16	..	.08 x .04	Arising	..
1740 x .32	.16 x .16	..	(.04 x .04) Arising	..	..
1848 x .40	.12 x .08	..	..	Arising	..
1952 x .44	..	.12 x .08	.08 x .06	..	..
2052 x .44	.28 x .24	..	.08 x .08	..	..
2116 x .14	.12 x .12	..	..	..
2256 x .56	.12 x .08	..	.08 x .06	..	..
2336 x .36	.12 x .14	..	Arising	..
2452 x .44	.12 x .14	..	.06 x .06	..	..
2520 x .16	.06 x .06	..
Percentage frequency	0	73	82	27	73	45	0
Mean area Sq. Mms.	0 ..	.25 ± .05 (.53 x .46)	.36 ± .01 (.20 x .17)	.013 (.12 x .11)	.007 ± .001 (.09 x .07)	..	..

* Measurements show length and breadth of in a collection of 100 buds. Measurements made by means of a micrometer and dissecting microscope.

The characteristic mode of growth in the inflorescence primordia may be described as a tendency to originate numerous growing apices. Large well formed inflorescence primordia have the appearance of a closely packed bunch of grapes (Figs 1, 2, 3, Plate 4)*, each "grape" representing a growing point. The primordium is a very complex branch system in which the branches elongate slowly but continue to divide rapidly.

* For Plates see facing page 308.

At the time of its origin, the anlage is simply a pad of meristematic tissue. As it enlarges, it develops into a bulbous protuberance which splits off a second growing point towards its base. This second apex represents the initial of the lowest branch of the system, and anlagen up to, and in this condition fall into the second of the two classes referred to above. Earlier formed anlagen rapidly develop the characteristic mode of growth of the inflorescence, and the primordium enlarges by the repeated formation of fresh apices. The mode of growth followed by anlagen which differentiate as tendrill primordia is essentially different and will be described in the following section.

It will be noted that the disposition of anlagen on the axis of the bud usually follows a definite plan. They arise opposite the 8th and 9th leaves, 11th and 12th, and at all except every third successive embryonic node, and may be represented as follows:—AA—AA—AA—etc.

Very often, an anlage is not developed at the 11th or 12th embryonic node and less frequently no anlage is present at the 9th. It is only occasionally, as pointed out previously, that an anlage arises at an embryonic node lower than the 8th.

Development gradually ceases in autumn, and the buds pass through a dormant period during winter in very much the same condition as they have reached by the end of March. The small amount of growth which takes place between mid-March and dormancy does not materially affect the relative development of the anlagen.

C. Fruit Bud Development Prior to Bud-Burst in Spring.

The appearance of the inflorescence primordium during the first half of August is similar to that represented in Fig. 2, Plate 4. Growth recommences about the middle of August, and is slow at first but increases progressively until the buds open about the first week in September. The inflorescence primordia increase considerably in size (Fig. 3, Pl. 4), and the axis of the bud grows forward forming new leaf rudiments and anlagen (Fig. 4, Pl. 4). Anlagen initiated during this period and during subsequent growth develop into tendrill primordia (at "t", Fig. 4, Pl. 4). The mode of growth of the tendrill primordia is essentially different from that of the inflorescence primordia. In the former, only a few growing points are formed, and these elongate rapidly to become branches. The tendrills, as well as the tendrill primordium, may be described as branch systems in which the branches elongate rapidly but only divide occasionally.

The anlagen which had reached a stage comparable to that shown at "a" in Figures 4 and 6, Plate 4, or were slightly more advanced, prior to the recommencement of growth during August, develop as tendrills also. These anlagen are comparable to those represented at the 10th and succeeding nodes in the advanced buds of Table II. (at "a" in Fig. 1, Pl. 4) and the majority of those at the 9th node in the normal buds (i.e. the group of anlagen less than 0.20×0.18 mm. in size during March).

Finally, the anlagen which were less than 0.40×0.30 mm. in size and greater than 0.20×0.18 mm. during March generally develop in spring to produce structures which are transition forms between tendrills and inflorescences. These transition forms are not of very frequent occurrence as may be determined by examination during early spring

subsequent to bud burst, but all gradations from perfect inflorescences to perfect tendrils may be found. In this connexion, it is interesting to note that in the majority of inflorescences, however, one branch is in the form of a tendril.

Primordia of typical transition forms are illustrated at "tr", Figs. 5 and 6. The primordium in Fig. 5 will probably develop into a tendril with perhaps a few flowers on some branches, whilst that represented in Fig. 6 may become more like a true inflorescence and produce a number of flowers.

It will be apparent, therefore, that the anlagen at the time of their origin are potentially similar, and that the inflorescence and tendril are homologous structures. Under the conditions controlling growth during late spring, summer, and autumn, anlagen develop into inflorescence primordia. Conditions under which growth recommences in spring, however, are totally different and are associated with the rise of the sap. Under these conditions, anlagen develop as tendril primordia.

In view therefore of the facts that—

- (a) well developed inflorescence primordia continue to develop in spring in the same manner as in the previous season, and
- (b) medium sized anlagen, which have begun to develop into inflorescence primordia, change their mode of growth when encountering spring conditions and develop into transition types instead,

it seems reasonable to assume that—

- (i) the mode of growth characteristic of the inflorescence is acquired by anlagen during their development in late spring, summer, and autumn, and when acquired this growth mode persists in spring, notwithstanding the changed conditions.
- (ii) anlagen, which have formed late in the season, and which, therefore, have not acquired a characteristic mode of growth, develop when new growth conditions are encountered in the spring entirely according to those conditions.
- (iii) anlagen, which have begun to grow in the way of inflorescence primordia, but which have not differentiated sufficiently to acquire this characteristic, are so affected by the new conditions in spring that their mode of growth is altered.

D. Flower Differentiation and Development.

The inflorescence primordia, as noted in the previous section, increase considerably in size during the period following the rise of the sap in mid-August. The differentiation of the flowers, however, does not occur until the time when the buds are on the point of bursting.

The first indication of flower initiation is the division of each growing apex into three more or less equal parts. In Fig. 1, Plate 5, a portion of a large inflorescence primordium, prior to initiation, is depicted, and in Fig. 2 of the same plate a smaller portion of another inflorescence

is shown, in which the division of the growing apices into three is illustrated. Each of the three growing points represents a flower primordium.

Differentiation occurs over the whole inflorescence almost simultaneously, and takes place in the basal branches only very slightly in advance of the apical branches. As soon as differentiation is accomplished, therefore, further branching of the inflorescence is prohibited. This fact is to be specially noted, as it means that the number of flowers which an inflorescence may produce is determined by the amount of growth which is made by the inflorescence prior to the differentiation of the flowers. Most of the growth and branching of the inflorescence occurs during the period from mid-August to bud-burst, but it is highly probable that the extent of the growth of an inflorescence during this period is very largely dependent upon the stage of development it had reached at the end of the previous autumn.

In Figs. 3-6, Plate 5, the development of the flower is illustrated. In Fig. 3, the sepals have been formed, whilst in Fig. 4 a more advanced stage is depicted in which the stamens are arising.

It is an interesting fact to note that the flowers in different inflorescences and in different parts of the same inflorescence all reach the same stage of development at the one time. This feature was particularly noticeable in material collected on the 23rd September, 1930 (Fig. 4). Apical and basal branches of many inflorescences were examined, and, in each case, the flowers were at approximately the same stage in their development.

Shortly after the origin of the stamens, and prior to the initiation of the carpels, the petals curve inwards and downwards, and fuse together along their ventral surfaces. The outer cells of the incurved portion of the petals are irregularly and loosely disposed. Growth of the petals forces their surfaces together, the loosely disposed surface cells becoming interlocked. Further division of these cells completely establishes the connexion. The fusion of the petals results in the formation of the corolla lid or operculum, which separates circumscissily when the flower opens. In Fig. 5, Plate 5, the fusion of the petals and the origin of the carpels are illustrated. Further growth results in the development of the stamens and carpels and origin of the ovules.

In 1930, pollen was formed on the 6th-7th of October by the tetrad division of the spore mother cells, and the megaspore was distinguishable in the ovule by the 13th. Further development was not followed in detail, but a large and apparently normal embryo sac had developed by the 24th October, just prior to the opening of the flower.

In 1929, development was later than in 1930 throughout the season.

The fact that the differentiation of the flowers of the inflorescence does not take place until the buds are on the point of opening in spring has not so far been generally recognized. Goff 1901⁽¹⁾ was of the opinion that flowers are unquestionably formed during the season previous to their expansion (in the grape). Chandler⁽²⁾ misquotes Bioletti⁽³⁾ as stating that the flower parts of the grape, *Vitis vinifera*, are formed during the season before the flowers open, and this opinion

(1) "Investigations of Flower Buds." Agric. Expt. Station, Wisconsin, Ann. Rept., 1901, p. 816.

(2) "Fruit Growing." (Houghton and Mifflin, U.S.A.), 1925, p. 51.

(3) "Vine Pruning in California." Univ. Calif. Agric. Expt. Station, Bull. No. 241, Pt. 1, 1914.

is usually quoted in text books and manuals. Winkler⁽¹⁾, however, recognized the fact that parts of the flower were formed after the buds had opened.⁽²⁾

3. Relation to Yield.

In view of the fact that two important factors controlling yield are the number and size of the inflorescences, it becomes evident from the foregoing that more attention should be directed to the rate of development of the anlagen during summer and autumn. The destiny of the anlagen is determined by their development during this period. The number of anlagen which differentiate as inflorescence primordia is dependent upon the rate of growth of the anlagen prior to winter dormancy, and the ultimate sizes of the inflorescences are largely controlled by the amount of growth made during the same period.

A comparison of the conditions prevailing during the periods when the anlagen form inflorescence primordia and when they differentiate as tendril primordia indicates the nature of the conditions which are conducive to inflorescence differentiation.

The conditions obtaining during late spring, summer, and autumn are characterized by the gradual slowing and final cessation of vegetative growth translocation of sugars to the maturing grape, followed by the conversion of sugar products, and the storage of starch. The conditions obtaining during early spring are characterized, on the other hand, by the re-conversion of starches to sugars, commencement of vegetative growth concurrent with the rise of the sap, followed by a progressive increase in the rate of vegetative growth. A comparison of these sets of conditions suggests that the early cessation of growth in summer and the rapid accumulation of starch may be conducive to the differentiation of anlagen as inflorescence primordia.

The following instance lends strong support to this contention. In one experimental field, owing to abnormal weather conditions, an early loss of crop occurred in December, 1931. In the succeeding year, however, the bud fertility (fruitful shoots/total buds) of these vines was 60 per cent., in marked contrast to the values of from 37-40 per cent. attained in other fields where the 1931-32 crop had been harvested. It might be inferred that, consequent on the premature loss of crop, there was an early accumulation of starch within the annual wood, and this in turn tended towards the differentiation of a high proportion of anlagen as inflorescence primordia.

Experimental work, based on the conclusions drawn from the observations communicated in this article, is at present in progress. In one series of experiments, an attempt is being made to influence the development of the anlagen and primordia during summer and autumn by cultural means. The object of a second series is to obtain more information in respect to the factors influencing anlagen differentiation and

(1) "Pruning and Thinning Experiments with Grapes." Univ. Cal. Agric. Expt. Station, Bull 519, 1931, p. 47.

(2) Subsequent to the presentation of this article for publication, a paper entitled "Flower Bud Formation in the Concord Grape," by J. C. Snyder, has appeared in the *Botanical Gazette*, Vol. 94, No. 4, p. 771. Apart from minor differences, some of which are evidently of a varietal character, such as the number of inflorescences per shoot, this account of the development of the inflorescence and flower of the vine agrees with our observations. The coalescence of the calyx into a cap has not been noted by us in the Sultana, however. Snyder does not deal with the relationships between inflorescence and tendril primordia upon which the significance of our communication depends.

inflorescence primordia development. The process of initiation and differentiation on a large number of shoots is being studied each season. Growth records and measurements are carried out on these shoots, and an attempt will be made to correlate characters of vegetative growth of the shoot with the process of anlagen formation, and the tendency to differentiate a large proportion of these as inflorescence primordia.

4. Acknowledgments.

The writers wish to express their appreciation of the helpful advice and criticism tendered to them during the course of these studies by Dr. B. T. Dickson, Chief of the Division of Plant Industry, C.S.I.R.

The Effect on the Body-Weight and Wool Production of Merino Sheep of adding Sulphur to the Diet.*

By *A. W. Peirce, B.Sc.†*

1. Introduction.

Steyn (1931 and 1932) reported some experiments in which increases in weight and wool production of sheep followed feeding 5 to 30 gm. of sulphur to them weekly. The sheep experimented with were mostly full-mouthed, but they increased 40 and 50 per cent. in weight during the first twelve months, and a further 20 to 30 per cent. in the next twelve months, so presumably they were in poor condition at the beginning. Steyn does not mention the diet given or consumed.

Evidence at present available does not suggest that the sulphur-containing amino-acid, cystine, can be synthesised by the animal organism from simpler compounds of sulphur. Westerman and Rose (1927) showed that thioglycollic acid and dithio-dipropionic acid could not be utilized for cystine production by the rat. Experimenting with the same animal, Lewis and Lewis (1926) and Rose and Huddleston (1926) (and Beard (1925-6) with mice), found that taurine, a derivative of cystine, does not supplement a cystine-deficient diet either for maintenance or growth. Daniels and Rich (1918) found that inorganic sulphates could not supply the cystine deficiency of a ration nor spare the maintenance demand for cystine in rats, and Geiling (1917) that flowers of sulphur did not prevent the decline in weight of mice on a diet which could be rendered satisfactory by the addition of cystine. Muldoon, Shiple, and Sherwin (1924) showed that in dogs fed with a carbohydrate diet insufficient cystine was available to detoxicate brombenzene. Sulphur supplied as free sulphur, sulphate, or sulphide was unable to bring about detoxication, whereas cystine could do so. Even d-cystine cannot be substituted, in the rat, for the naturally occurring l-cystine, according to the recent experiments of du Vigneaud, Dorfmann, and Loring (1932). So far, the only substance discovered which

* Submitted for publication 7th April, 1933.

† An officer of the Division of Animal Nutrition, C.S.I.R., located at the Division's head-quarters, University of Adelaide.

seems to be able partially or wholly to replace cystine in a diet is the amino-acid methionine. The recent observations of Jackson and Block (1932) suggest this conclusion.

The primary object of Steyn's experiment appears to have been to ascertain the amount of sulphur which could be added to the diet of a sheep without poisoning it. He points out (p. 491) the defects of his experiment, and that before coming to any definite conclusions as to the effects of sulphur on the weight and wool production of sheep it would be advisable to conduct experiments on groups of sheep of more homogeneous compositions than those he employed.

However, as the average increment of weight in the sheep observed by Steyn improved with the increase in the amount of sulphur given, and the wool production in those receiving sulphur was 10 to 40 per cent. greater, it was decided to undertake an experiment to see whether the addition of flowers of sulphur (brimstone and treacle) to a diet, the protein of which was largely furnished by casein which has a low cystine content, would lead to the growth of more wool. On this diet, experience had shown that wool production was below normal.

2. Arrangement of Experiment.

As the experiment was concerned mainly with wool production, mature sheep were selected in order to eliminate complications caused by growth which would have intervened had young animals been used. Eight ewes almost five years old, and two wethers nearly four years old, were divided into two groups each containing four ewes and one wether. The difference between the mean weights of the two groups after shearing was 5 per cent., and the groups were also matched so that they were as similar as possible in wool character. The lightest and heaviest sheep weighed 32 and 52 kg. respectively. The animals were in fair condition only at the beginning of the experiment, as they had been grazing on natural pasture which is poor in Adelaide in autumn.

The basal diet consisted of a mixture of 420 gm. of chaffed wheaten straw, and 240 gm. of chaffed wheaten hay, together with 100 gm. of molasses, 50 gm. of casein, and 15 gm. of linseed oil per day. This ration, which contained approximately 62 gm. of digestible crude protein, 430 gm. total digestible nutrients, 1,500 calories metabolizable energy, and 240 gm. of starch equivalent, proved to be a slightly super-maintenance ration for the ewes, although not for the wethers, which were about 30 per cent. heavier; it was decided, however, to feed the same ration to both ewes and wethers.

One group of sheep received 2 gm. of flowers of sulphur daily in addition to the basal diet.

The sheep were brought into pens from pasture in the middle of April, 1932, and were first fed hay chaff with which was mixed a gradually increasing proportion of straw, until, by the end of a fortnight, they were receiving the experimental ration. This was given in two portions. The first, in the morning, consisted of some straw and hay mixed with the daily ration of molasses. To this was added casein in the case of the control animals, and the casein-sulphur mixture in the case of the sulphur-fed sheep. Within a short time, this feed was entirely consumed, thus ensuring that the sulphur was taken. In the afternoon, the remainder of the straw and hay was fed, together with

the linseed oil which was poured over the roughage. With the exception of one of the controls which invariably left a small amount, this portion of the ration was also consumed. After about five months, all the sheep, but particularly the sulphur group, began to leave some of the second meal, so that it was decided to feed hay chaff instead of hay and straw at this feed. This resulted in change in the total daily roughage to 360 gm. of hay and 315 gm. of straw. Following this, the animals began to eat rather better, although some of the sulphur group still left a portion of the second feed of the day uneaten.

Shearing took place at the beginning of the experiment, and the animals were again shorn seven months later, in the middle of December. The greasy wool cut by each sheep at this second shearing, representing the growth in 32 weeks on the experimental diet, was weighed. The wool from the individual sheep was then put through a fleece breaker of the type described by Wilson (1928). A representative sample of this "willeed" wool was then selected and scoured by the commercial method, and the total production of clean scoured wool by each sheep calculated.

Weekly weighings of the sheep took place unless wet weather made this impossible. The experimental sheep were dipped five weeks before the end of the experiment, as the remainder of the flock was then being dipped.

3. Results.

(i) *Weight increase.*

The mean weekly weights are shown in Table I. From this it will be seen that both groups of sheep increased slowly in weight at the same rate for about the first five months, the growth curves being almost parallel during this period. Following this, the decreased consumption of roughage led to a decline in weight, which was similar for both groups. With the increase in the proportion of hay chaff in the roughage, consumption increased, as also did weight. However, increase in weight occurred to a greater extent in the case of the controls, which almost overtook the sulphur group. Over the whole period, the sulphur-fed animals increased from 40.8 to 45.3 kg., a gain of 4.5 kg., whereas the controls increased from 38.6 to 44.8 kg., an increase of 6.2 kg. The weight increases, although somewhat in favour of the controls, are not significantly different, especially as the greater part of the difference occurred in the last four weeks.

The addition of sulphur to the diet of these sheep did not cause an increase in weight greater than that of the controls.

(ii) *Wool Production.*

The weight of greasy wool and the calculated clean scoured weight cut by the individual sheep, together with the mean of the groups and the quality (count) of the individual fleeces, is given in Table II. From these figures, it is seen that there is a slight difference in weight, too small to be significant, in favour of the control group. There was also little difference between the groups as regards count. Before the experiment began, the animals were paired up as closely as possible as to wool quality, in order that the two groups should be as nearly equal as possible in this respect.

TABLE I.—MEAN WEEKLY WEIGHTS.

Week.	Sulphur.	Control.	Week.	Sulphur.	Control.
	kg.	kg.		kg.	kg.
0	39.9	38.4	17	45.0	43.7
1	41.1	38.6	18	45.6	44.1
2	41.4	38.9	19	45.3	43.3
3	40.4	38.2	20	46.5	44.0
5	40.8	39.4	22	46.5	44.3
7	42.1	40.1	23	46.3	44.7
8	43.0	41.2	24	45.9	44.4
9	43.1	41.4	25	45.5	44.1
10	44.0	42.1	26	46.0	43.9
11	43.1	41.7	27	44.5	42.2
12	44.2	42.2	28	43.8	43.2
13	43.6	42.7	29	45.0	44.6
14	44.4	42.9	30	45.0	44.4
15	44.7	43.0	31	45.8	45.5
16	44.4	44.1			

TABLE II.—THE PRODUCTION OF WOOL FLEECE.

Group.	Sheep.	Sex.	Greasy Wool (kg.).		Clean Scoured Wool (kg.).		Count.
			Experimental Period (223 days).	Calculated for Twelve Months.	Experimental Period (223 days).	Calculated for Twelve Months.	
Sulphur	W ₁ 27	♀	1.96	3.21	1.270	2.080	60
	W ₁ 43	♀	1.98	3.24	1.405	2.300	60
	W ₁ 44	♀	1.91	3.13	1.125	1.840	70
	W ₁ 50	♀	1.91	3.13	1.130	1.850	60
	W ₁ 51	♂	2.48	4.06	1.660	2.715	60-64
	Mean	..	2.05	3.35	1.32	2.16	..
Control	W ₁ 31	♂	2.51	4.11	1.630	2.670	60-64
	W ₁ 2	♀	2.07	3.39	1.485	2.430	58
	W ₁ 14	♀	2.35	3.85	1.460	2.390	60
	W ₁ 34	♀	1.95	3.19	1.175	1.925	64
	W ₁ 35	♀	2.04	3.34	1.050	1.720	64
	Mean	..	2.18	3.57	1.36	2.23	..

4. Discussion.

The experiment described by Steyn (1931 and 1932) was, as the author himself realized, unsatisfactory in some respects. There was lack of uniformity in the animals used. Their weight at the beginning of the experiment ranged from 55 to 116 lb., and, as the sheep were either full-mouthed or four-toothed animals at that time, many of them must have suffered from severe nutritional stress during their lifetime, or else were of very different breeding. The fact that the increases in weight amounted to as much as 90 per cent. during the first twelve months of the experiment shows that the food supply of the animals during the experimental period was greatly superior to that before. Unfortunately, the diets before and during the experiment are not

mentioned. It would not be just to attribute the higher average rate of increase in weight of the groups receiving sulphur to the nutritive effect of this mineral.

A similar criticism would apply to the conclusion that the sulphur increased the production of wool. The variations in the amount of greasy wool produced by sheep in the same group are so large (reaching 78 per cent. in one case, in 1930, and 107 per cent. in 1931) that it is doubtful whether there is a significant difference between the groups.

In the experiment recorded in the present paper, the sheep did not differ greatly in weight and were all mature animals. The food consumption of all the sheep, apart from the period of four weeks previously mentioned, was within 10 per cent. The largest variation between the weight of greasy wool cut by any two sheep in the same group was 30 per cent. The production of clean scoured wool, however, showed a maximum difference of 55 per cent.

The experiment shows that the weight increases were not materially different in the groups; in fact the slight difference noted was in favour of the controls. Thus, what proved to be a maintenance ration for the control sheep was also a maintenance ration for those receiving 2 gm. of sulphur per day.

The differences in wool growth were also of no significance, although they, too, were slightly in favour of the control group. Feeding of sulphur had no effect in increasing wool growth.

5. Conclusion.

The administration of 2 gm. of sulphur per day for a period of seven months did not increase the wool production of mature sheep.

While this article was in the press, one by Seddon appeared (*Aust. Vet. J.* 9: 154, 1933) giving the results of a somewhat similar experiment. Two groups, each of 7 wethers 13 months old, even in body weight, size, and wool quality, were run together on pasture for two years. One group received 10 gms. of sulphur three times per week. The result showed that the sulphur had no material effect on body or fleece weights.

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The Microphotography of the Living Virus of Pleuro-Pneumonia of Cattle.

By A. W. Turner, D.Sc., D.V.Sc.*

The purpose of this brief note is to introduce and explain some photographs of the causal organism or "virus" of pleuro-pneumonia of cattle.

The living organism was first observed as minute oscillating points by Nocard and Roux in 1898, when grown by them in collodion sacs in the peritoneal cavity of the rabbit.

A little time afterwards, it was cultivated *in vitro* by them in collaboration with Borrel, Salimbeni, and Dujardin-Beaumetz. In 1910, Borrel, Dujardin-Beaumetz, Jeantet, and Jouan published a paper on the morphology of the causal organism, based mostly upon stained centrifuged deposit of cultures, but they included a drawing illustrating certain forms seen by the aid of dark ground illumination. Their work was quickly challenged in Germany by Freiburger (1912), who declared the forms described by the French workers were merely precipitates, &c.

Examination by dark ground illumination does not appear to have been very successful in the hands of any of the later workers. As late as 1923, Frosch, in Germany, investigated cultures by photographing them in ultra-violet light, and found only tiny spheres and a few Y-shaped elements, and as a result considered the organism to be allied with the yeasts. Barnard, in 1925, in England, during his work with Gye on the etiology of cancer, studied cultures of pleuro-pneumonia virus by the most efficient method of investigation known to science, i.e., photography by dark ground illumination using ultra-violet light, and similarly found only tiny spherules; as a result, he suggested an extraordinary method of multiplication by a process of budding. The photographs of both Frosch and Barnard are far from satisfactory or convincing. Wroblewski (1931), who has published an excellent account of the morphology of the organism as revealed by stained preparations of cultures, could find nothing characteristic by dark ground examination of cultures. As a result of this work, he has claimed that the organism reproduces both asexually and sexually.

Interest in the morphology followed upon our introduction of a new culture medium known as "filtered V.F.-ox serum," and which gives heavy growths overnight.† Examination by ordinary dark ground illumination was consequently commenced. Enormous numbers of organisms in various stages of growth were readily found; work on its morphology and life history as revealed by a study of the living organism has been going on for about twelve months, but until recently attempts to photograph the organism have been unsuccessful, the amount of light passing through the microscope by this method of illumination being relatively small.

However, certain results have at last been obtained, and what are undoubtedly the first satisfactory photographs of the living virus of pleuro-pneumonia are presented in the accompanying photographs.‡ Our

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† This medium will form the subject of a paper to be published elsewhere. It is essentially the medium used by us in our black disease studies (C.S.I.R., Bulletin 41), containing 10 per cent. of serum and sterilized not by heat but by filtration through a Seitz E.K. disc.

‡ See Plate 6, facing page 309.

success over workers with superior equipment may be attributed partly to the culture medium, and partly to the technique used for producing the photographic records, which has been made possible by the valued assistance of Mr. A. T. Dann, M.Sc. Briefly, the photographs were taken by supporting, in contact with the ocular of the microscope, a Leica camera fitted with an Elmar F. 3.5 lens of 5 cm. focal length, at full aperture and focussed at infinity. The microscope was fitted with a 60 X apochromatic homogeneous oil immersion objective, with iris diaphragm giving a numerical aperture from 0.85 to 1.00; compensating oculars were used, the most useful being the K 15. The magnification thus given would be $60 \times 15 = 900$ if the image were projected on a screen removed the conventional 25 cms. from the ocular; but as the image was actually focussed in the camera on the sensitive film about 5 cm. from the ocular, the actual magnification was one-fifth of 900, or 180 diameters, and its luminosity was increased proportionately. The Leica camera uses cinematograph film, and makes negatives 37 mm. x 25 mm. The particular film used was Agfa Superpanchromatic, of such fine grain that the tiny negatives readily allowed the enlargements illustrated to be prepared, showing the organism at a final magnification of 1,250 diameters. Even with this film, which is probably the fastest at present known, exposures could not be reduced much under one second, and consequently some of the photographs show evidence of Brownian movement. The source of light was a Phillips 75 c.p. Pointlight with aplanatic condenser; the dark ground condenser was the Zeiss Cardiod.

A perusal of the photographs will reveal that the organism typically produces a branched mycelium that may reach a surprising size. The long filament with terminal branches in Fig. 1 is over 65μ long; the longest we have yet seen measured 155μ long. Obviously, such forms cannot be filtrable; but the organism owes this property to its extraordinary facility for fragmenting. The mycelia during observation may within a few minutes become 'beaded', very closely resembling streptococci, the elements of which thereupon proceed to break away as approximately spherical cocci about 0.2μ in diameter. Streptococoid forms are produced very early during growth. Essentially similar branched mycelia can be seen in pleural "virus" of natural cases of pleuro-pneumonia, provided it is examined immediately after removal; within a few hours, only the tiny coccoid forms may be found.

Some of the photographs illustrate small spheres similar to those illustrated by Barnard and by Frosch; in cultures on serum V.F. agar, spheroidal forms predominate, many of them at closer examination revealing themselves as concavo-convex or flat discs; but it must be conceded that they are far from representing the characteristic and most striking stage of the life history; they become more common in "filtered V.F.-ox serum" as the cultures age, and are possibly another filtrable phase.

An article covering the above work in more detail will be published shortly.

Throughout the investigation, the greatest assistance has been given by my colleagues, Messrs. A. D. Campbell, B.V.Sc., and A. T. Dick, B.Sc., who have frequently drawn my attention to cultures and preparations suitable for study.

Radio Research Board: Fifth Annual Report (for the Year ended 30th June, 1933).

The Radio Research Board of the Council is constituted as follows:—Professor J. P. Madsen (University of Sydney), Chairman; Mr. H. P. Brown (Director-General, Postmaster-General's Department); Electrical-Commander F. G. Cresswell (Department of Defence); and Professor T. H. Laby (University of Melbourne). Its previous annual report was published in this *Journal* (Vol. 5, No. 4, November, 1932).—Ed.

1. General.

During the past year, the work of the Board has been continued on its former lines, the main investigations concerning (i) the reflecting layers of the ionosphere, chiefly from the point of view of fading problems, and (ii) atmospherics.

The original three year arrangement regarding the financing of the Board has now expired, but the two co-operating bodies, namely, the Postmaster-General's Department and the Council for Scientific and Industrial Research, have entered into another agreement to finance the Board's work for a further period of three years as from the 1st July, 1933. The Department will continue to meet three-quarters of the total cost of the Board's operations. This measure of stability to its investigations—so necessary if effective work is to be done—is appreciated by the Board.

Further changes in the staff of the Board have taken place. Mr. R. O. Cherry, M.Sc., resigned as from the beginning of 1933. Two new appointments have recently been made, the appointees being Dr. G. Builder, M.Sc., Ph.D., and Dr. H. C. Webster, M.Sc., Ph.D. Both of these are Australian graduates, the former from the University of Western Australia, and the latter from the Universities of Tasmania and Melbourne. For the last few years, they have been gaining post-graduate experience in Great Britain. It is expected that they will reach Australia in about September, 1933. In the first instance, Dr. Webster will be allocated to work on atmospherics, and Dr. Builder to fading and propagation problems.

2. Work on Fading and the Ionosphere.

The completion of the experimental transmitting equipment at the University of Sydney at the end of last year has made possible a considerable extension of the Board's investigations of fading and the ionosphere.

In the previous work of the Board carried out at Jervis Bay*, it was evident that under the particular conditions that applied, the chief reflecting medium concerned in the return of indirect rays to the earth was a layer at a height of about 110 kms., i.e., the Kennelly-Heaviside Layer. However, definite indications of the effect of the Appleton Layer at a height of about 250 kms. were observed, and it appeared desirable to make further investigations of this reflecting region. For this purpose, a different set of experimental conditions was required.

The opportunity for these observations occurred with the completion of the Sydney University transmitter. Field intensity measurements† of a "B" class station located in Sydney and working at a frequency

* See Radio Research Board—Report No. 2, Council for Scientific and Industrial Research, Bulletin 59.

† Described by Green and Wood in *J. Inst. Eng. Aust.*, Vol. 5, No. 1, January, 1933.

of 1,125 kilocycles per second were used in the selection of a suitable set of conditions for the new Appleton "frequency-change" experiments. As a result of this short survey of both ground and sky wave intensities, it was concluded (i) that the University transmitter should operate at a mean frequency of about 1,500 kilocycles per second, (ii) that a special transmitting aerial should be available, in addition to the normal type, in order to increase the sky wave radiation, i.e., an aerial whose radiator was a horizontal wire one half wavelength long, and (iii) that the existing receiving site at the Military Camp, Liverpool, N. S. Wales, distant 25 kms. from the sender, was suitable.

Preliminary tests at Liverpool showed that, even at this short distance from the transmitter, sky wave intensities were adequate for the "frequency-change" experiments, and during the latter part of 1932 an extensive programme of ionosphere height measurements was undertaken. Observations were made during the greater part of the night, both in Melbourne, where the received signal was due entirely to sky waves, and also at Liverpool, where there was also a ground wave present for reference purposes.

The results obtained at the shorter distance showed that the Appleton Layer was more often the reflecting agent than the Kennelly-Heaviside region; thus it was possible to make a much more extensive investigation of the upper layer than had been possible at Jervis Bay, where penetration of the lower layer was only infrequently observed.

The simultaneous observations made in Melbourne, distant 800 kilometres from the sender, have thrown considerable light on the mechanism of interstate broadcast reception at distances of this order. On those nights when the check measurements at Liverpool indicated that the Kennelly-Heaviside Layer was in operation, the reception in Melbourne was comparatively steady, and the photographic records of the special "frequency-change" tests showed that the received signal was composed of two sky waves of approximately the same amplitude. On other nights, when the Liverpool measurements showed that the upper layer was the chief reflecting agent for sky waves received at short distances, the long distance reception was irregular, variations in signal occurring very frequently; at these times the "frequency-change" tests showed that either two or three sky waves were being received, one of them having a much longer path than the others and being of less intensity.

Although the records taken during this period have not yet been fully analysed, it is possible to form the general conclusions that:—

(i) In the case of long distance reception, slow fading is caused by interference between, and by changes in amplitude of, two sky waves, each returned to the earth by the Kennelly-Heaviside Layer. Fast fading is ordinarily due to an indirect ray from the Appleton Layer.

(ii) In the case of short distance reception, slow period fading seems always to be due to interference between the ground wave and a sky wave singly-reflected from the Kennelly-Heaviside Layer. Fast fading has been traced, at different times of the night and on various occasions, to (a) the reception of a doubly-reflected wave from the Kennelly-Heaviside Layer in addition to the singly-reflected wave from the same layer, to (b) the singly-reflected wave from the Appleton Layer at times when the main

sky ray is that from the Kennelly-Heaviside Layer, and to (c) the doubly-reflected wave from the Appleton Layer at those times when the main sky ray was also from the same layer. There have also been occasions during the sunset period, when the origin of fast fading has escaped detection.

The same field-intensity set which had been used in obtaining data for the operating conditions of the Sydney University transmitter was later converted for measurements at a frequency of 200 kilocycles per second (1,500 metres wavelength), the stations observed being the Naval Board's transmitters VHD and VHJ at Garden Island (Sydney Harbour), and at Flinders Naval Depot, Western Port, Victoria. With this equipment, measurements of ground wave attenuation, night-time severity of fading, intensity of sky wave, and the intensity of atmospherics, have been made in a number of representative localities in south-eastern Australia, both along the coast-line and inland. In consequence, much information regarding the fading of long waves over different types of country and at different distances from the transmitter has been obtained. The results of this work have recently been published (*J. Inst. Eng. Aust.*, Vol. 5, No. 6, June, 1933).

Steady progress has been made at Liverpool with the design and operation of apparatus to measure simultaneously all of the properties of downcoming waves, including length of atmospheric path, angle of incidence at the ground, amount of lateral deviation from the direction of propagation of the ground wave, relative intensities of the normally and abnormally polarised components of magnetic force, angular phase difference between these components, and the sense of rotation of the total magnetic force.

Preliminary results already obtained tend to indicate that the amount of lateral deviation for an east to west direction of transmission is small, but tests of the apparatus have not yet reached the stage when a definite announcement can be made as to the accuracy of the measurements. Concurrently with this experimental work, it has been found necessary to prosecute a number of theoretical investigations concerned with the reception of more than one downcoming wave in addition to the ground wave. The results show that care will have to be exercised in the selection of suitable conditions for these experiments.

3. Work on Atmospherics.

Equipment.—The use of cathode ray direction-finders for observing the intensities of atmospherics and locating their sources was described in last year's report. This work has been continued in co-operation with the Solar Observatory, Mt. Stromlo, F.C.T., particularly with a view to providing more accurate information on the sources shown on the directional recorder charts.

The recorder—which is located at Mt. Stromlo—previously worked on a wavelength of 30,000 metres, and the aerial system rotated once every quarter of an hour. Owing, however, to the good propagation on this long wavelength, it was found difficult to distinguish on the charts between sources at 500 to 5,000 kms. and those at several thousand kms. The wavelength has therefore been reduced to approximately 10,000 metres where the variation of intensity with distance is greater. It was found also that the speed of rotation was too great to record accurately the sources of cyclone activity to the south. Though

these are not very important as regards radio interference, they are of meteorological significance as indicating barometric depressions, generally over the sea. The time of rotation of the aerial system and recording drum has therefore been altered to half an hour. The instrument is now giving reliable and easily interpretable records of all sources distant not more than 2,000 kms. by day and some 5,000 kms. by night.

A similar recorder which was remodelled for the purpose in the workshop of the Natural Philosophy Department of the University of Melbourne has been installed at the Magnetic Observatory at Watheroo in Western Australia, so that, in future, a much more accurate analysis of the sources in and beyond Northern Australia will be possible.

As mentioned in last year's report, an auxiliary receiver operating a cathode ray tube was used to measure the intensity on 300 metres of atmospherics at the same time as their intensities and directions were observed on 3,000 metres on the cathode ray direction-finder, thus enabling comparison of the intensities on the two wavelengths. Further information was obtained by applying a time-base to this cathode ray tube so as to give an indication of the composition and duration of the atmospherics. Information on the duration of atmospherics was obtained also by photographic registration with an Einthoven galvanometer. A Cambridge Thread Recorder was also found to be useful in recording "noise levels" due to a large number of atmospherics at the same order of intensity.

Results.—The analysis of a year's charts of the recorder was described in last year's report and the general conclusions stated. Since then, a more detailed analysis of the close sources—within 2,000 kms. of Canberra—has been carried out. Only days when cathode ray direction-finder observations were also available were considered, as the latter enabled the locations of the sources to be determined. The region within the range of observation was divided into equal areas, and the sources in each area for the year compared as regards the number, average activity, and average duration. The diurnal and seasonal variations of these factors were also studied.

The main points brought out by the analysis are:—

(i) In general, the annual number of sources increases towards the Equator. The topography also affects the number considerably.

(ii) The activity of sources shows a steady increase with approach to the Equator.

(iii) The average duration of sources increases slightly towards the North, but the most noticeable feature is the marked difference between sea and land sources. The average duration for land sources in the area studied is 6 hours. They occur mainly between noon and 6 p.m. For sea sources, the average is 10 hours, and the times of occurrence are distributed much more uniformly over day and night.

(iv) In the North, the land sources are of the tropical type, and are practically confined to the summer months, while in the South they are of the cyclonic type and occur much more evenly throughout the year.

Since this knowledge is available for a considerable part of the continent, it may be utilized to estimate the amount of interference

with radio reception, providing the intensity of the resulting interference is known.

The intensities measured in most of the past work have been peak intensities on the cathode ray tube. These have been compared with the deflections for continuous-wave transmissions, and it has been found that, on a broadcast receiver on a wavelength of 300 metres, the peak intensity corresponds to that which would have been produced by a transmitter located at the source of atmospherics radiating a carrier wave power of the order of 2 kilowatts. It has been found that the peak intensity of an atmospheric is approximately proportional to the wavelength, so that the corresponding power on wavelengths other than 300 metres regarded as a source of interference will vary as the square of the wavelength.

This knowledge is of value in assessing the probable degree of interference to broadcast listening, but several steps are necessary before the final stage of application can be reached. Since the laws of propagation of radio waves are reasonably well understood, it is possible to estimate the electrical quantities that will influence listening conditions at the receiving end, but the interpretation of these quantities in terms of the listener's experience when listening to a programme requires the introduction of psychological and other factors.

Preliminary observations on this aspect showed that, for several individual listeners when listening to a programme of classical music, the interference from occasional atmospherics did not become appreciable until the peak intensity of the atmospherics was at least equal to the carrier-wave intensity of the station received.

The above information is of greatest value for close sources, where the direct ray will predominate. At night, however, the indirect or sky ray becomes of importance, as the intensity due to it is of the same order for distances between 300 and 1,000 kms. The atmospherics will then be received from over a great area, and may be in such great numbers as to give what approximates to a continuous "noise level" in a receiver of sufficient sensitivity. For satisfactory reception, the received signal intensity must be considerably in excess of this level. Tests carried out, using a Cambridge Thread Recorder, on a number of summer nights when some very active sources were being received mainly by the indirect ray, showed that the interference from this cause would be scarcely audible to a listener receiving a programme of music if the carrier-wave field strength of the station was at least 0.5 m.v./m. on a wavelength of approximately 300 metres.

The duration and composition of the individual atmospherics is of importance in determining the degree of interference caused, and some preliminary observations on this aspect have been made by using a time-base on a cathode ray tube, and by photographic registration on an Einthoven galvanometer. These have shown that the average atmospheric from a close source consists of a succession of impulses of varied intensity occurring in rapid succession. The total duration of a single atmospheric varies from less than 0.1 second to 1 second, or even more on occasions. The average duration was of the order of 0.4 seconds for those observed.

Future Work.—Preparations are being made for the transference of part of the equipment to a site in Queensland to carry out a more intensive study of the very active sources which occur there in the summer. The frequency of close sources will also permit of more

ready observations of intensities on shorter wavelengths, and of the characteristics of atmospherics and the resultant interference. It will also provide a longer observing base for simultaneous direction-finding and a location which will be particularly suitable for the sea area to the east.

4. Publications.

The following publications have been issued during the past year as a result of the Board's investigations:—

(a) *Publications of the Council for Scientific and Industrial Research.—Bulletin 68.*—"Radio Research Board: Report No. 5, Atmospherics in Australia—I.", by G. H. Munro, M.Sc., A.M.I.E.E., and L. G. H. Huxley, M.A., D.Phil.

(b) *Individual Articles.*—(For convenience, summaries of those reports are also included).

1. "A Field-Intensity Set," *J. Inst. Eng. Aust.*, Vol. 5, No. 1, January, 1933, by A. L. Green, M.Sc., and H. B. Wood, B.E., B.Sc.

The paper describes a field-intensity set for studying both ground and sky waves. A novel feature, making for simplicity of calibration, was the use of a vacuum-tube millivoltmeter, specially designed to have a high sensitivity. Its use enabled the components of the artificial signal injection apparatus to be calibrated directly; the accuracy of the complete assembly therefore finally depended only on the precise measurement of the geometrical dimensions of the loop aerial, and on the calibration of the vacuum-tube millivoltmeter. The use of a substantially linear vacuum-tube voltmeter, following the amplifier in the receiver, greatly facilitated the measurement of the low field-intensities. A few results of practical tests with the apparatus in measuring field-intensities of both ground and sky waves from a "B" class transmitter located in Sydney are given.

2. "Measurements of Attenuation, Fading and Interference in South-Eastern Australia, at 200 kilocycles per second," *J. Inst. Eng. Aust.*, Vol. 5, No. 6, June, 1933, by G. H. Munro, M.Sc., A.M.I.E.E., and A. L. Green, M.Sc.

The same field-intensity set described above, but converted for use at a wavelength of 1,500 metres, was employed.

(i) *Attenuation.*—Equivalent ground conductivities, in electromagnetic units, were deduced for the following types of country:—For transmission along the coast, ground wave path mainly over sea, the conductivity was 10^{-13} to 5×10^{-13} . Transmission over flat country, conductivity 10^{-13} ; over flat wooded country, conductivity 5×10^{-14} . Transmission over undulating wooded country, conductivity 10^{-14} . Transmission over country, including mountain slopes, conductivity 3×10^{-15} .

(ii) *Fading.*—The observations made in the areas where the carrier wave was exhibiting the variations characteristic of fading permit the following deductions to be made for a frequency of 200 kilocycles per second:—For coastal districts, where much of the transmission path is over sea water, the 50 per cent. fading ring is not closer than 550 kms. to the transmitter. For inland districts, where the intervening country is undulating and wooded, 50 per cent. fading is first encountered at about 250 to 350 kms. from the transmitter. For inland districts, where

some part of the transmission path is over mountain slopes, the 50 per cent. fading ring occurs at about 200 to 250 kms. from the transmitter. The greatest values of indirect ray intensity recorded were a little higher than 0.1 millivolts per metre for 1 kw. radiated.

(iii) *Interference*.—The general noise-level due chiefly to atmospherics propagated at night from great distances, did not exceed 0.015 millivolts per metre.

3. "The Limiting Polarisation of Downcoming Radio Waves Travelling Obliquely to the Earth's Magnetic Field," by W. G. Baker, B.E., D.Sc., and A. L. Green, M.Sc., accepted for publication in the *Proc. Inst. Radio Eng., New York*, 5th April, 1933.

The basis of this paper was Radio Research Board, Report No. 3 (Council for Scientific and Industrial Research, Bulletin 60). Since this report was published, however, the theoretical investigation has been extended, and the following summarises the complete paper:—

It is found that, as a downcoming wave leaves the ionosphere, the polarisation tends to a definite limit. The shape of the polarisation ellipse is determined solely by the frequency of the wave relative to the critical frequency and by the angle between the direction of propagation and the lines of force of the earth's magnetic field. The orientation of the ellipse is such that the major and minor axes are perpendicular to the direction of propagation; the major axis is in the plane containing the direction of the earth's field and the direction of propagation. The sense of rotation of the electric vector contained by the ellipse is left-handed when the direction of propagation of the "ordinary" downcoming ray makes an acute angle with the earth's field; the rotation is right-handed when the angle is obtuse. The sense of rotation of the "extraordinary" ray is the reverse. By a simple transformation of the principal components of electric force, namely, those directed along the axes of the ellipse, to components respectively in the vertical plane containing the sending and the receiving stations, and parallel to the ground, it has been shown to be possible to predict the polarisation of a downcoming wave, as measured at the ground, at any given distance and in any direction from the transmitter. As a practical example, maps have been drawn on which there have been marked lines of equipolarisation, the conditions being those for transmission from station 2BL, Sydney, New South Wales, frequency 855 kilocycles per second. An important theoretical point which appeared in the course of the analysis was that, in the ionosphere, the true direction of propagation is oblique to the wave-front. Practically, this means that a wave propagated obliquely to the earth's magnetic field will be laterally deviated; the amount of deflection depends on the gradient of ionization in the layer.

1. "The Polarisation of Sky Waves in the Southern Hemisphere," by A. L. Green, M.Sc., transmitted to the Institute of Radio Engineers, New York, for publication in the Proceedings.

The article is based on a part of Radio Research Board Report No. 2, Bulletin No. 59 of the Council for Scientific and Industrial Research. It describes the experimental measurement of right-handed polarisation of downcoming waves as compared with Appleton's observations of left-handed rotation in the Northern Hemisphere.

5. Acknowledgments.

Once again, acknowledgment is due to a number of organizations and individuals for the valuable co-operation they have furnished. The help of the Postmaster-General's Department and the Universities of Melbourne and Sydney has been continued on the previous lines. The Department of Defence has afforded valuable assistance in several ways, but notably by the loan of apparatus and the accommodation of equipment at Laverton (Victoria) and Liverpool (New South Wales). The Commonwealth Solar Observatory at Mt. Stromlo and the Watheroo Magnetic Observatory of the Carnegie Institution are also co-operating most helpfully in connexion with the work on atmospherics.

The Composition of Different Regions of Mounds of *Eutermes exitiosus* Hill.

By F. G. Holdaway, M.Sc., Ph.D.

Erratum.

The author of this article, which appeared in the previous issue, has now noted that in portion of the discussion on the lignin : cellulose ratio the ratio was given incorrectly. At the bottom of page 164, the last paragraph should read:—

“The ratio of lignin to cellulose in its food would therefore be about 1:2, and this ratio has been changed by digestion of cellulose to 4:1. (A similar change from a lignin:cellulose ratio in camphor wood of about 1:2½ to a ratio of about 4:1 in the nest is recorded by Oshima(1919) for *Coptotermes formosanus*. . . .”

Botulism of Sheep in Western Australia and its Association with Sarcophagia.

By H. W. Bennetts, D.V.Sc.

Erratum.

In the article entitled “Botulism of Sheep in Western Australia, and its Association with Sarcophagia,” and appearing in the previous issue, it was stated that on one property where green lucerne, rabbit carcasses, and mounds of rabbit droppings were all exposed to a mob of sheep, they showed a decided preference for the droppings. This statement was based on a report from a source which was believed to be quite authentic, and was accepted in good faith. Recently, it has been established that the facts were misstated. No lucerne was exhibited. It has been frequently noted, however, as in this instance, that sheep show a marked appetite for rabbit droppings, which are preferred when only dry feed is available.

PLATE 1.

(*Blue Stain in Pinus radiata (insignis) Timber. See page 244.*

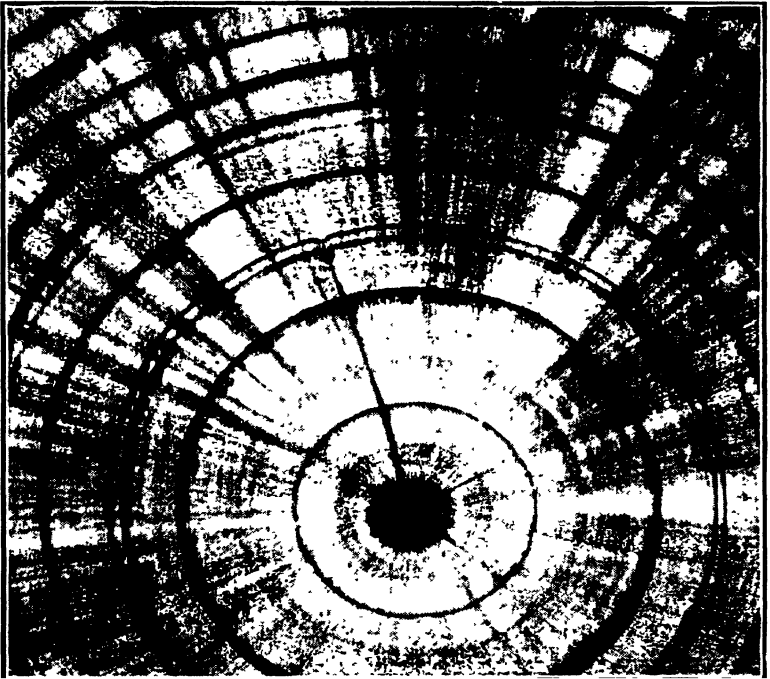
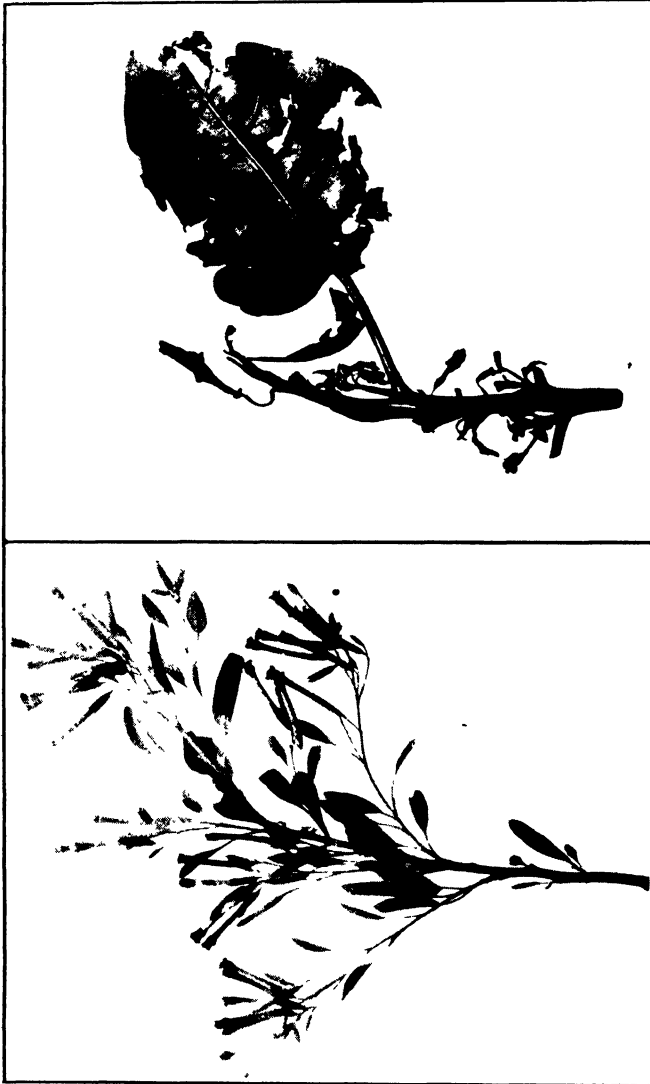


FIG. 1.—End section of a 3" × 3" *P. radiata* square showing the penetration of blue stain (the dark radial streaks).

PLATE 2.

(Downy Mildew (Blue Mould) of Tobacco. See page 260.)



(Left).—*N. glauca* Graham. Tree tobacco. A shrub 10 to 15 feet high. Leaves ovate, varying from $1\frac{1}{2}$ to 9 inches in length, fleshy and glaucous with a long slender stalk. Flowers terminal, and in a loose panicle, tubular, greenish yellow. $1\frac{1}{2}$ inches long. Capsule ovoid and similar in appearance to a tobacco capsule. The photograph shows a twig in flower.

(Right).—*N. glauca* attacked by downy mildew of tobacco. The growing shoot has been killed, and new shoots arising from the axils of the leaves have been attacked. The ragged appearance of the large leaf is due to the diseased areas having fallen away. The general appearance is very much like that of tobacco attacked in the autumn.

PLATE 3.

(Foot and Root Rots of Wheat in Australia. See page 269.)

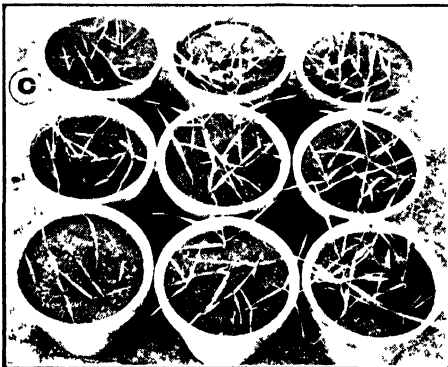
POT EXPERIMENT OUT-OF-DOORS—FEDERATION WHEAT IN STERILIZED SOIL.



- (a) Plants from grain inoculated with conidia of *Fusarium culmorum*. All seedlings are apparently healthy.



- (b) Plants from grain inoculated with a mixture of spores of *Fusarium culmorum* and *Urocystis tritici*. Only 45 plants out of 81 standing are apparently healthy, the others, 36, are dying or dead.



- (c) Plants from grain inoculated with spores of *Urocystis tritici* only. All seedlings are apparently healthy. The photograph of the controls was omitted because in general appearance they were not different from either A or C.

PLATE 4.

(*Fruit Bud Studies. II. The Sultana. See page 285.*)

LONGITUDINAL SECTIONS OF SULTANA BUDS. ($\times 36$.)

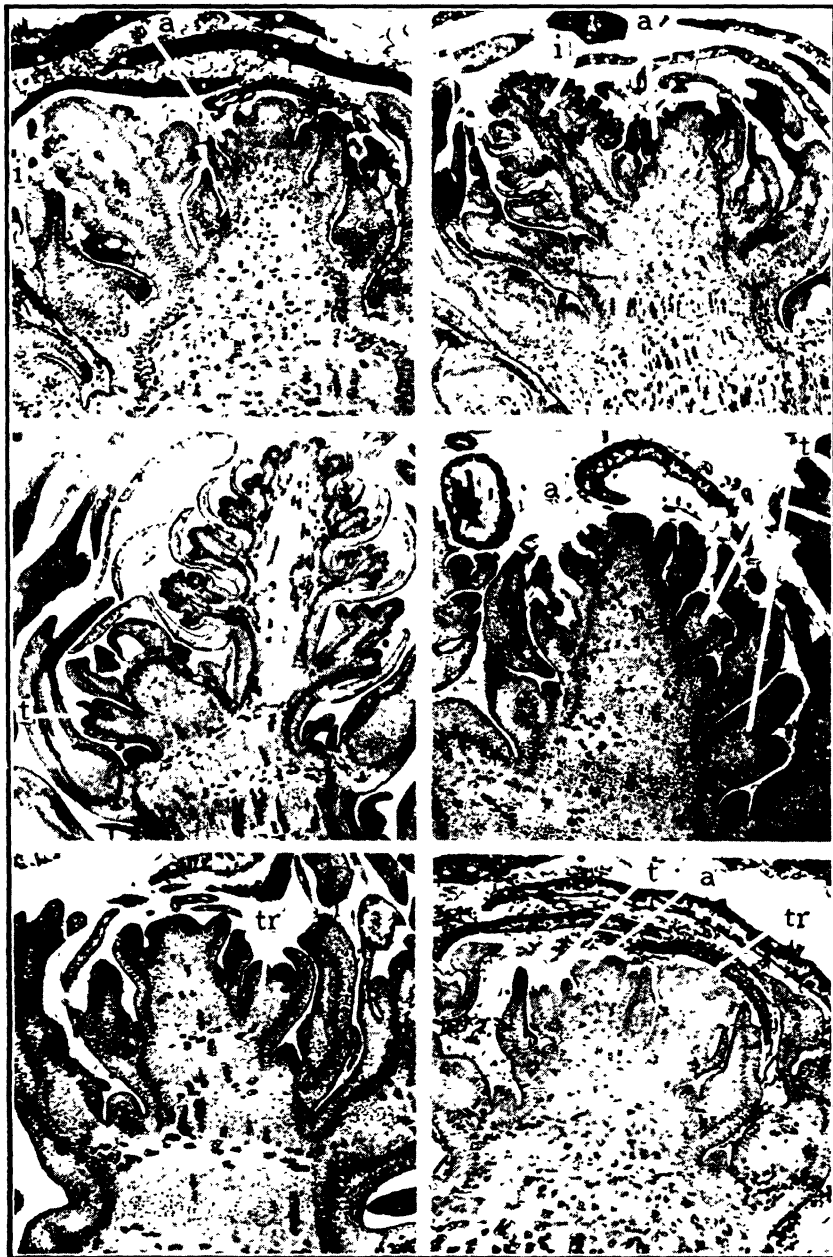


FIG. 1 (top left). - The 7th bud 14.3.30 showing a typical inflorescence primordium (i). At "a" is an undifferentiated anlage. FIG. 2 (top right). - Stage reached by most advanced inflorescence primordia by end of August. An anlage at "a". FIG. 3 (centre left). - The inflorescence during rapid growth just prior to opening of the bud. Tendril primordium at "t". FIG. 4 (centre right). - Typical tendril primordia at "t" with an anlage at "a". A bud with no inflorescence, 2nd September. FIG. 5 (bottom left). - At "tr" there is a transition form primordium. FIG. 6 (bottom right). - At "tr" a transition form primordium is shown. At "a" is an anlage, whilst at "t" an anlage which is differentiating as a tendril primordium is shown.

PLATE 5.

(*Fruit Bud Studies. II. The Sultana. See page 285.*)

SECTIONS OF THE INFLORESCENCE OF THE SULTANA. ($\times 72$, EXCEPT FIG. 6.)



FIG. 1 (top left) —A small portion of the inflorescence represented in Fig. 3, Plate 4, prior to flower formation. FIG. 2 (top right) —The first indication of flower initiation is seen in the division of each growing apex into three. FIG. 3 (centre left) —Three flower primordia with sepals just formed, 8th September, 1930. FIG. 4 (centre right) —The sepals, petals and stamens formed in three flowers. The petals curving inwards prior to fusing. 23rd September, 1929. FIG. 5 (bottom left) —A single flower showing origin of the carpels and petals fused 2nd October, 1929. FIG. 6 (bottom right) —The flower on the 13th October about a fortnight before bloom. Mature pollen is present in the anther. ($\times 30$).

PLATE 6.

*(The Microphotography of the Living Pleuro-Pneumonia
Virus of Cattle. See page 299.)*

PLEURO-PNEUMONIA "VIRUS" TAKEN BY DARK
GROUND ILLUMINATION.



FIG. 1.—Long mycelium with tuft of branches
at each end. —Total length about 45μ
Cult. in V.F.-O.S., 20 hours old $\times 1250$

PLEURO-PNEUMONIA "VIRUS" TAKEN BY DARK
GROUND ILLUMINATION.



FIG. 2.—Cult. in V.F.-O.S., 20 hours old,
showing mycelial fragments and spherical
form. $\times 1250$.

NOTES.

The Register of Agricultural Research.

One of the first recommendations of the Standing Committee on Agriculture (see this Journal 1: 58, 1927), which is representative of the various State Departments of Agriculture and of the Council, was that a record of the individual agricultural researches in progress in various localities in Australia should be prepared and kept up to date from time to time. It was considered that this record would be useful in connexion with the general movement for the dissemination of the results of scientific research and for the avoidance of overlapping.

Some years ago, the first record was prepared under the title "The Register of Agricultural Research." The various State Departments of Agriculture, Universities, the Council, &c., have recently brought the relevant information concerning their research work up to date, and a new Register has been prepared. Copies have just been distributed to State Departments of Agriculture, Universities, the Council, and main Public Libraries throughout the Commonwealth. In addition, a few copies have been sent to Great Britain for the information of agricultural research authorities there.

It will be quite impossible to supply any particular investigator with a copy, as the Register has not been printed. Copies are available for perusal, however, on application to the organizations mentioned in the preceding paragraph.

The Division of Forest Products—Visitors to Laboratories.

Early in November, Mr. A. T. J. Bianchi, Officer-in-charge, Technology Section of the Forest Research Institute, Buitenzorg, Java, will commence a stay of some months at the laboratories of the Division of Forest Products. This Institute proposes to erect experimental seasoning kilns and commence a series of investigations into the kiln seasoning of the timbers of the Dutch East Indies. While at the laboratories of the Division, therefore, Mr. Bianchi will make a comprehensive study of the Division's seasoning research, as well as of the types of kilns in commercial use in Australia.

Accompanying Mr. Bianchi will be one of the engineers of the Royal Packet Navigation Company, Mr. C. J. Andriess, who will take an active part in the erection and operation of a trial kiln which is to be erected at a commercial plant in addition to one or two laboratory kilns at the Research Institute.

Mr. F. Gregson, Utilization Officer of the Western Australian Forests Department, is also spending two months in the Division to study the methods used in attacking problems of utilization and seasoning.

The Gas Storage of Foods : A Review of the Present Position.

A paper on the above subject by Dr. Franklin Kidd, M.A., D.Sc., of the Low Temperature Research Station, Cambridge, was read on the 14th February last before the North-West Branch of the British Association of Refrigeration, and has been published in the *Proceedings of the British Association of Refrigeration*, Vol. XXIX., No. 2, 1932-33, pp. 130-145.

The first investigations by the British Food Investigation Board on gas storage were undertaken as a result of a series of publications in 1914 on the influence of carbon dioxide upon the germination, respiration, and life duration of seeds. At the outset, the dominating idea was that atmosphere control might prove effective without temperature control, and thus serve as an alternative method to the use of cold storage. This idea was soon shown to be without foundation. It was also realized that different products would differ in their reaction to atmosphere control, and it was decided to confine investigations in the first place to one kind of fruit, namely, the apple. Every year, only one set of apple storage experiments can be carried out, and hence progress was slow.

In the course of two or three years, the experiments were developed to the scale of a chamber holding 8 tons, but without temperature control. At this stage of the work, several facts emerged. The first was that under the conditions of restricted ventilation with fresh air many varieties tended to scald badly in gas storage, though otherwise well preserved.

Scald is a superficial browning of the skin, which greatly disfigures apples and renders them susceptible to fungal rotting. Another important fact brought to light by these experiments was that in bulk storage without temperature control the self-heating of the fruit was a serious factor. During cold weather, the average inside temperature in the store was about 50° F. higher than the outside temperature, whilst during warm weather the difference was over 10° F. It was found that the beneficial effect of the atmosphere control in retarding the ripening was counteracted by warm autumn temperatures in the early days of storage. An experiment was accordingly made in which refrigeration was used only in the hot weeks of early autumn. The results of these trials were unexpected. Some of the varieties of apples used were found to be seriously affected by a new type of injury like that known as low temperature internal breakdown. In contrast with this, the other varieties were preserved in a manner and to a degree far exceeding that possible with cold storage alone.

This experiment definitely marked the end of the idea that gas storage without temperature control was an alternative method to ordinary cold storage. It cannot be too definitely stated that, for nearly all purposes, temperature control is essential in the gas storage of fruit.

By this time, the Low Temperature Research Station at Cambridge had been completed, and it was thus possible to make use of greatly improved facilities for more accurate and comprehensive experiments. The variety of apple used was the Bramley's Seedling, which is the most important English culinary variety. The experiments showed very clearly that, for Bramley's Seedling, 10 per cent. oxygen and 10 per cent. carbon dioxide at 40° F. gave results much superior to those of cold storage and air. As soon as the results of these experiments, which were carried out in 1926-27, became known, growers began to embark

upon the construction of refrigerated gas stores for the storage of Bramley's Seedling. There are now five large commercial gas stores in operation in Kent.

Though the economic possibilities of gas storage for fruit were thus definitely established, a great deal of further work had nevertheless to be done. With this in view, the Ditton Laboratory of the Food Investigation Board has been equipped for semi-large scale gas storage work. In two years, a great deal of further information has been obtained. One of the most instructive and useful lessons has been the demonstration of the great ease with which gas injury may be incurred if safety limits either of oxygen or carbon are overstepped. Moreover, the critical importance of temperature in regard to gas tolerance limits has been strongly emphasized. It has been a general rule to find serious gas injury at 34° F. (breakdown type) and at 50° F. (brownheart type) and none at all at 39° F.

Turning to recent developments with regard to the gas storage of meat and fish, Dr. Kidd states that it has been fully demonstrated that the time limits for the chilled storage of these foods can be considerably extended by the use of atmospheric control in addition to low temperature. The reason for this is quite simple. The time limits of cold storage are set in the main by the activity of living micro-organisms—fungi and bacteria. It is these living organisms which cause putrefaction, taint, and rancidity. If the vital activity of these organisms can be slowed down or stopped by controlling the carbon dioxide and oxygen content of the atmosphere, a very promising line of development is opened up.

As regards pork, chilled storage life can be doubled by the use of high percentages of carbon dioxide. Pork has been kept in perfect condition for over two months at 0° C. in commercial carbon dioxide, and thereafter tasted better than fresh pork, as it was more tender.

At the Torry Research Station, Aberdeen, it has been found that fish packed in ice and stored in air was definitely sour and stale after fourteen days, whereas similar fish packed in ice and stored in carbon dioxide showed no signs of sourness after 28 days.

Beef, when stored in air at 29.5° F., was spoilt in 30 days, but when stored in an atmosphere of 10 per cent. carbon dioxide was in good condition at the end of 60 days. These results have been followed up on a semi-commercial scale by Dr. J. R. Vickery with very successful results. (See article on page 233.)

Similar successful results have been obtained in the storage of unsmoked mild cured bacon, which has been held in perfect condition for eighteen weeks at 32° F. Gas storage of eggs is an established commercial procedure. In Europe, there are a number of stores using this process.

Carbon dioxide and oxygen are among the most obvious cases of control in the storage atmosphere. There are, however, many gases and vapours which are likely to have physiological effects upon fresh foods in storage, such, for example, as ethylene, ozone, ammonia, aldehydes, and alcohol vapours. Until recently, experiments with such substances were conducted in a haphazard manner without much attention to the critical factor of the exact dosage required to produce specific effects. To-day, progress is being made because attention is being directed to the strength and duration of treatments.

Changes in Kiln-Dried Timber during Transit from Australia to England.

Contributed by W. L. Greenhill, B.E., Division of Forest Products.

During recent years, the quantity of seasoned timber shipped from Australia to England has been steadily increasing. The conveyance of seasoned timber by boat immediately raises the question of the probable change in moisture content of the timber which may occur during transit. It has been commonly thought that an increase will occur, and buyers and sellers, therefore, have frequently inquired as to the most suitable moisture content for shipment, so as to provide for delivery of the timber as specified. For this reason, an investigation of the changes which are normally to be expected in kiln-dried timber *en route* has been carried out by the Division of Forest Products with the co-operation of the Forest Products Research Laboratory, Princes Risborough, England, and two of the principal shipping companies concerned.

The procedure in the investigation has been to prepare sample boards from a consignment of timber which is to be shipped to England. The sample boards are weighed and measured, and then distributed in bundles amongst the timber as it is loaded into the boat. Upon arrival in England, the samples are collected, again weighed and measured, and then tested for moisture content. Data relating to the conditions in the hold during the voyage, to other cargo in close proximity, and to the general state of the shipment on unloading are also collected.

Two test shipments of the above nature have now been completed. Both consisted of kiln-dried and re-conditioned machined Victorian mountain ash flooring, which was handled in bundles of 37 boards each. Three sample bundles, containing the same number of boards, but only 3 feet long, were distributed in each consignment. The sample bundles were carefully end-coated to ensure that any moisture changes in these short lengths would be comparable with the changes in the rest of the shipment, in which the lengths ranged from 9 to 20 feet. In both shipments, the stowage conditions were considered very satisfactory, good ventilation being provided throughout the voyages. In the first shipment, the timber was in an insulated hold with a quantity of wool; in the second, it was stowed with a quantity of other timber. The two voyages occupied 55 and 38 days respectively. A summary of the moisture content changes and changes in the widths of the sample boards during the two voyages is given in the following table:—

Shipment.	Bundle.	Average moisture content of boards in bundle		Average change in moisture content.	Average width of boards in bundle		Average change in width.
		When Shipped.	On Arrival		When Shipped.	On Arrival	
1	1	% 14·3	% 14·1	% -0·2	inches 3·26	inches 3·25	inches. -0·01
	2	12·7	12·7	0	3·26	3·26	0
	3	12·4	12·6	+0·2	3·27	3·26	-0·01
2	1	13·6	13·3	-0·3	3·26	3·26	0
	2	13·1	13·1	0	3·26	3·26	0
	3	13·2	13·2	0	3·27	3·27	0

It will be seen that during transit the moisture changes of the bundles as a whole were negligible. The indicated changes in widths of boards are within the limits of accuracy imposed by the methods of measuring. Both tests serve to indicate that, if properly stowed, timber shipped from Australia at moisture contents from 12 to 14 per cent. is unlikely to change to any appreciable extent during transit to England.

Tests of a similar nature have been carried out by the Forest Products Laboratories of Canada, Vancouver Laboratory, on changes in kiln-dried timber during shipment from Canada to various parts of the world, including Australia, and similar results have been obtained.

Recent Publications of the Council.

Since the last issue of this *Journal*, the following Bulletins and Pamphlets of the Council have been published:—

Bulletin No. 74.—"Observations on Soil Moisture and Water Tables in an Irrigated Soil at Griffith, N.S.W.," by Eric S. West, B.Sc., M.Sc.

The investigations discussed form part of a programme of work which the Council is carrying out at Griffith in co-operation with the Water Conservation and Irrigation Commission of New South Wales. After the structure of the soil and such factors as the field capacity, the "sticky point," and the wilting point have been dealt with, the effect of weather conditions on the water table is considered at length. A subsequent section deals with the effect growing plants have on soil moisture and the water table. The value of lucerne as a means of controlling a rising water table, and thus of obviating harmful effects on citrus, is shown.

Bulletin No. 76.—"A Soil Survey of the Hundreds of Laffer and Willalooka, South Australia. Report of the Division of Soils," edited by J. K. Taylor, B.A., M.Sc.

The publication deals with the survey of an area in South Australia representative of some 6,500 square miles of country in South Australia and some 4,300 square miles in Victoria, all under a 15 to 20 inch rainfall. Three soil types have been named and described in full. It is shown that, with the exception of a small proportion of the area, the bulk of the soils offer very small prospects of economic returns at the present time.

Pamphlet No. 43.—"Investigations on the Buffalo Fly, *Lyperosia exigua* de Meij." I. "The Host Preference of *L. exigua* (resumé)," by Dr. B. J. Krijgsman and G. L. Windred, B.Sc.Agr.; II. "The Relation between the Adult *L. exigua* and Mammalian Faeces," by Dr. B. J. Krijgsman and G. L. Windred, B.Sc.Agr.; III. "Some Food Reactions of the Larvae of *L. exigua*," by G. L. Windred, B.Sc.Agr.; and IV. "The Influence of Moisture on the Larvae of *L. exigua*," by G. L. Windred, B.Sc.Agr.

The Pamphlet gives the results of some of the work carried out at the State Veterinary Institute, Buitenzorg, Netherlands East Indies, on the life history and habits of the buffalo fly. The investigations were carried out by officers of the Council, who were kindly accommodated at the Institute, as part of the Council's general inquiry into the Australian buffalo fly problem.

Pamphlet No. 44.—"The Chemistry of Australian Timbers: Part 3.—The Chemical Composition of Four Pale-coloured Woods of the Genus *Eucalyptus*—*E. gigantea*, *E. obliqua*, *E. regnans*, and *E. sieberiana*" (Division of Forest Products—Technical Paper No. 9), by W. E. Cohen, B.Sc., A. G. Charles, and A. B. Jamieson, M.Sc.

The Pamphlet covers a continuation of the analytical work the Division of Forest Products is carrying out on the Australian eucalypt timbers. It is of particular interest in that it deals with the group of species which have proved to be most suitable for paper making in Australia. Some regular differences in certain chemical factors, such as total pentosans, percentages of "solubles" in various solvents, and "soluble" ratios, were found, and the possibility of employing these as an aid to identification is indicated. In addition, variation of chemical composition within a species was studied, and its possible influence on wood pulp yields is discussed.

Pamphlet No. 45.—"Australian Export Apple Cases" (Division of Forest Products—Technical Paper No. 10), by W. M. Carne and R. F. Turnbull, B.E.

This publication gives the results of an extensive series of tests carried out largely at the instance of the Standards Association of Australia and aimed at the ultimate standardization of the Australian export apple case. The two main types of case now in use, namely, the Canadian and the Australian dump, are described, and the disadvantages of using more than one type are stressed. Data regarding the protective value of the different types (based on the damage occurring during packing and in drop tests), the strength of cases, and the effect of cool storage conditions on case timbers, are presented. It is shown that under the conditions of packing used the dump shape gives better protection to its contents than the Canadian shape, and that unduly tight packing is found to be a source of bruising. Bruising can be reduced by the use of all-round corrugated strawboards. It is recommended that a standardized dump case not less than 18" x 9" x 14½" in internal measurements be adopted as the standard export apple case.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. .—"Studies in the Phosphorus Requirements of Sheep—I," by C. J. Martin, M.D., D.Sc., F.R.S., and A. W. Peirce, B.Sc.

Bulletin No. .—"Methods for the Identification of the Pale or Light-coloured Woods of the Genus *Eucalyptus*" (Division of Forest Products—Technical Paper No. 12), by H. E. Dadswell, M.Sc., Maisie Burnell, B.Sc., and Audrey M. Eckersley, M.Sc.

Pamphlet No. 46.—"The Holding Power of Special Nails" (Division of Forest Products—Technical Paper No. 11), by Ian Langlands, B.E.E.

Pamphlet No. .—"Properties of Australian Timbers—Part I." (Division of Forest Products—Technical Paper No. 13). Collated and edited by H. E. Dadswell, M.Sc.

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